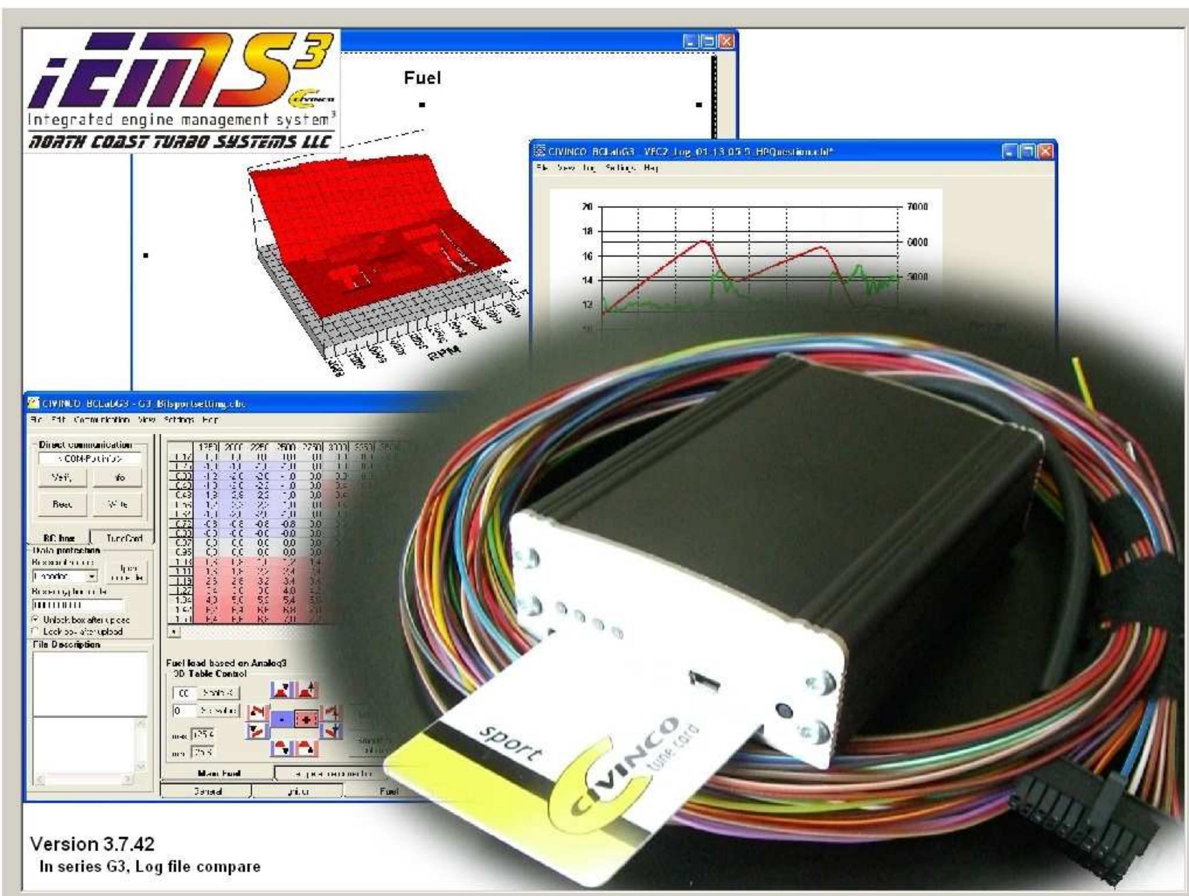
Tune It!

It's my car, and I want to Tune It NOW!

Performance Tuning for the Modern OBDII Compliant Vehicle

By North Coast Turbo Systems LLC



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INTRODUCTION:

Welcome to the world of aftermarket performance tuning. If you are reading this document, then obviously you have an interest in tuning your own vehicle. Once you have grasped some basic methods, techniques and terminology, you will be able to successfully tune your modified vehicle. Proper tuning will help you to achieve optimum performance and eliminate poor drivability.

We will focus on the techniques available to tune your vehicle and the use of the IEMS3 “In Series” engine management system.

The IEMS3 is vastly different from more common “piggyback” units, and we will explore what those differences are as well.

Please read through this entire document and any literature supplied with your unit. Additional reading regarding the basics of fuel injection and in particular the functioning of a modern OBDII compliant vehicle ECU would also be helpful. Your vehicles service manual should provide a discussion of the function of various systems, individual components, and sensors.

It is also a good idea to read the troubleshooting/testing sections related to malfunction codes for the particular area of interest associated with your vehicle.

With the right components, tools, and knowledge, you can make your vehicle more enjoyable or if you disregard caution and simply charge ahead, you can cause damage if the tuning is not done correctly.

HOW THINGS WORK:

What is this CANbus thing I hear about?

The modern OBDII compliant (meaning it meets and maintains compliance to the Federal Emissions Standards) vehicle uses a very complicated and intelligent series of computers. Today, most vehicles have numerous modules (or nodes) connected together over what is known as a Controller Area Network bus (CANbus) system. The modules have their own “address” (like your computer’s IP address on the internet), and if one is missing, the system will call foul and may take a time out.

This is similar to the central nervous system you and me were born with. In nearly all cases, if you disconnect a module from the system, you will get a Malfunction Indicator Light (MIL) or some call it a Check Engine Light (CEL). Depending on the device disconnected, you may simply get a hidden trouble code as commonly occurs when changing audio equipment, or a particular system, such as Heating and Cooling, may cease to function all together. Worst case, the vehicle simply will not start or run.

When tuning these vehicles, one must keep this in mind at all times. Like it or not, we have to work with what is installed unless you want to strip down the vehicle and install old style, manually controlled and actuated equipment. This would be quite an expensive and time consuming task. Not to mention, your vehicle will likely no longer be legal to license and operate.

This is why you cannot simply take a full Stand Alone Engine Management system and install it in a modern vehicle, thereby pitching the original ECU (engine control unit). If we could simply replace the vehicle ECU, life would be easy, but we can't, so let's move on.

There are many different products by numerous manufacturers on the market. They will generally fall within a few categories regardless of who made it. So let's take a look at what they are, and what they can do.

The "Chip"

A chip is simply a small electronic module that plugs into the vehicle ECU plug or harness. They generally work by modifying certain signals to a new fixed value. In a lot of cases, this is nothing more than changing the Intake Air Temperature (IAT) sensor value to make the ECU think the air is colder than it really is, thus adding more fuel. Chips are a simplified version of the Piggyback unit discussed below. It has fixed settings and generally can not be adjusted by the end user.

The "Piggyback" unit

The "tunable" type of unit, are those commonly known as a "piggyback" unit. These are a secondary computer that rides on the back of certain engine sensors. They will intercept a signal, modify it, and send it to the ECU with the intent of making the ECU think the engine is operating under a condition different than it really is.

The primary basis for fuel control on these units is to offset the MAP (Manifold Air Pressure) or MAF (Manifold Air Flow) sensor signals so the vehicle ECU will see a lighter load on the engine and scale back the fuel injector pulse width, thus allowing larger than stock fuel injectors to be used. This is also known as MAP/MAF sensor voltage skewing, or indirect fuel management.

While this may have worked on older non OBD or OBDI compliant vehicles, today's OBDII compliant vehicles are far too smart for this old trick. The ECU adaptives will quickly see any signal modification that is constant or repeatable, interpret this as degradation of the component (in most cases), and will apply changes to its own internal ECU calibrations to get things back in line with the original parameters for operation of the vehicle.

In other words, the ECU "learns" around your changes and will apply adaptive correction, negating all your efforts. You ECU is what it is, why fight it, let's understand it and learn how to work with it. For modern OBDII compliant vehicles, MAP/MAF voltage skewing piggyback units are bad news, let's move on.

Handheld tuners

There are many handheld tuners on the market. They function by rewriting part of the information stored in the vehicle ECU. Generally, the parameters in the stock ECU are modified, rarely is the actual computer software code changed. Most handheld tuners come with several "canned" tunes, low octane fuel, high octane fuel, cold air intake and cat back exhaust, etc. These cover the more common simple vehicle modifications. If this is all that you have, and all you ever intend to do, then one can surely be found to meet your needs.

Handhelds will also give you numerous individual configuration options as well, speed limiter, rev limiter, transmission settings, tire size, rear end gearing, shift points, idle speed, etc. All good things to have, and well worth the cost of the unit alone, plus nearly all have scan tool capability as well as the ability to read and clear the MIL/CEL codes that may pop up form time to time. Some will give a narrow range of option to adjust fuel and/or timing, generally 10% or less.

All good things, helpful for minor tweaking, but they can't handle more serious power adders. For serious power adders, a more intrusive step is needed.

The Custom Tune

Here is where things get serious in short order. On older vehicles, (GM and Ford primarily) the actual ECU software in some cases has been "leaked" to the aftermarket or hacked, and either tuners or PC software is available where one can rewrite exactly how an ECU functions. An experienced tuner can make a heavily modified vehicle perform as if it was a factory power option.

Around 2004, the Federal Government really started to crack down on vehicle manufacturers regarding emissions compliance, and they have instituted some highly advanced encryption methods in their software to prevent the ECU from being modified. False warranty claims have also become a concern of the manufacturer, so expanding the encryption techniques and capabilities of the control systems to detect and report tampering is the rule, not the exception today.

Custom tunes are created using licensed software that is not available to the end user of the vehicle (most cases). Since the software opens up nearly all of the ECU parameters and tables, there is generally a very steep learning curve, in particular on new models coming to market.
Since the original vehicle manufacturer's software that operates the actual ECU is proprietary, there is vigorous enforcement and prosecution of copyright

infringements. Since the actual software programming is not being modified, the tuner is left to figure out how to manipulate the parameters and tables that can be accessed to achieve a particular goal.

It is not a simple matter of just changing a single parameter (spark for example), but it has to be approached from a three dimensional aspect and all of the cause and effects must be considered and changes made in those areas as well. The manufacturers spent considerable time and money to develop the operating envelope for the vehicle, and it is not a simple task to modify those parameters and still keep all other aspects of operation in check.

It is not uncommon for certain adaptives and functions to simply be “turned” off or desensitized to make the process simpler, however this practice can lead to unexpected results not to mention the vehicle will likely no longer pass emissions inspections as the ECU may not show up in a “Ready” state for testing. Modern ECU’s have very advanced adaptive capabilities and provisions to protect your investment from damage, it makes more sense to work with these capabilities rather than fight them.

The custom tune is loaded into the ECU via a handheld or laptop. It is important to obtain a back up file in case the original is lost, corrupted, or overwritten by a dealer ECU reflash.

The end user generally has no idea what was changed, and no ability to modify or tweak it without a trip back to a shop with the software and capabilities the original file was created from. A custom tune can range anywhere from about $300 for what is known as an e-mail “semi canned” tune, to as much as several thousand dollars for a full on, in person tune with dyno and road testing times involved.

These tunes generally work well for Naturally Aspirated engines; however, Forced Induction is another challenge all together as the original ECU programming does not have the needed parameters and tables built into it. Therefore a lot of manipulation has to take place to develop a new operating envelope and adapt what can be changed in the ECU to this. Sometimes it works out okay; many times it does not, as the ECU is being asked to do something it was never designed to perform. Almost always, there are residual drivability issues that remain as a result of modifying the parameters outside the norm for the particular ECU.

If you are going to have a custom tune created for your vehicle, here are some of the things to keep in mind before you spend your hard earned money. First, you are putting your trust in someone to perform brain surgery on your $40,000 vehicle. Seek out and talk to multiple people who have used the person/shop for tuning on your type of vehicle. Many times you can find people on various internet forums that have used a person/shop before. If you can, find someone close by with a similar vehicle that has a tune from the person/shop of interest and get a test drive to see just how well it performs.

Do they lock their tunes? Will they provide a back up file copy? Will they work with you to resolve any drivability issues after the initial session? Are they willing to tell you exactly what they are doing to the ECU, such as turning off functions, adaptives, areas they are modifying, etc? You are paying for it; you have the right to know what is going on and what you are paying for.

Many times, we see a Wide Open Throttle (WOT) tune session on a dyno and that is it. What about day to day street drivability? If you have things like high or low idle, surging on start up or at idle, poor gas mileage, jumpy throttle, sloppy shifting, degrading performance with either colder or warmer weather than when it was tuned, are all signs that very little thought was put into the drivability portion of the tune.

If end user tuning ability is your desire, we need to move on.

The Stand Alone Engine Management system

We have made mention of the Stand Alone in the introduction, but we will mention it again as they are commonly looked at as a possible solution to the tuning dilemma. As was mentioned, it is important to understand the vehicle ECU is just one of the many modules in a modern vehicle. Removing the ECU will have the effect of shutting down the entire vehicle control system.

A Stand Alone works very well on older vehicles without an ECU. To use one in a modern vehicle, you would need to strip out nearly every system in the vehicle and install direct control components as were used in older vehicles such as audio, power windows and locks, gauges, heat and AC controls, etc. But many other things would be lost, first and foremost is the vehicles emissions compliance, so depending on where you live, you might not be able to register and license ft for on road use.

Vehicle speed sensors, security systems, stability and torque management controls, automatic functions such as headlights, wipers, etc, would also cease to function as the controller that provides input to the relays that turn these items on/off would no longer be present.

So, a full Stand Alone Engine Management System is simply not an option for the modern OBDII compliant vehicle.

Programmable Calibrators

There are individual devices available that are known as a programmable calibrator. It is a device that is installed “inline” in the vehicle wire harness between certain engine sensors and the stock ECU. The programmable calibrator modifies these signals from the sensors and then passes the modified signal on to the ECU.

Generally these trick the ECU into doing things a little differently than it normally would thus providing some control to retune a modified engine. Generally, the programmable calibrator can modify a signal, clamp a signal, or delay a signal. If this sounds a little familiar, you are correct, a “piggyback” unit usually has numerous types of programmable calibrators combined in a single package. For clarity we will discus the various types from an individual basis as they can be very useful when used for specific purposes.

Signal Modifiers:

Signal Modifiers function by taking a sensor signal and changing it in some fashion. Nearly all voltage based signals in a vehicle operate on a 0 – 5 volt range. For example, the signal from the MAP sensor varies depending on the pressure in the manifold, with a corresponding voltage change the ECU will recognize and provide the appropriate amount of fuel by changing the fuel injector pulse width.

If a signal modifier is used to offset the actual voltage from the MAP sensor, then the ECU would see a different load on the engine, and make changes to the injector pulse width to provide what it thinks is the correct amount of fuel. This is MAP sensor voltage skewing that is at the heart of nearly every “piggyback” unit on the market today.

While these do not work well in regards to a MAP or MAF sensor, they can be of use for other less critical sensors which do not have the cross checking that takes place with MAP/MAF signals via ECU Adaptives.

An important point to remember is that if you are in Closed Loop mode, simply trying to add fuel will always result in the ECU modifying its internal parameters to remain at a 14.7 AFR. It will always win; give up that fight (or at least the approach). Signal modifiers are either voltage or frequency based; however the vast majority are voltage based, but both work the same.

Signal Clamps:

Signal clamps can be either voltage or frequency based as well. They limit a signal to a preset level so it does not go any higher, or in some cases drop below a certain level.

You may see signal clamps used to clamp signals like engine coolant sensor signals, and vehicle speed sensor signals. Engine coolant sensors are usually voltage based where devices like vehicle speed sensors are frequency based.

Once the clamping level is reached the signal clamp will not allow the signal to change beyond the preset limit. This is a very useful device, well proven, and invisible to the ECU so it can not learn around it as the sensor continues to behave as it originally performed up to its limit, generally the normal top of its voltage range.

These are very popular for use in clamping (limiting) MAP or MAF sensor output so a stock sensor is not over ranged causing a MIL/CEL code.

Signal Delay:

By intercepting a signal and delaying when it gets to the ECU, then time critical signals can be altered. The most typical use for this technique is to control ignition timing.

Modern vehicles use a magnetic sensor that sits near a ring that is attached to the crankshaft . This ring will have teeth (or notches) on it. When one passes by the sensor, it creates a pulse into the sensor lead. These rings may have a tooth or two missing at one point or may not have any teeth until a certain point. It is this difference in the teeth and the signal it generates that tells the ECU what position the crankshaft is at. The ECU must have this information to decide when to fire the spark plugs and the fuel injectors.

If the pulsed signal is intercepted and delayed before it is allowed to continue to the ECU, the timing of when the spark plugs are fired is changed. If it is delayed a little, then we can retard the ignition timing. If we delay it a lot, such as 350 degrees, we can end up make the spark plugs fire 10 degrees sooner, making it advance the ignition timing (not all engines can advance timing with this method).

Depending on the desired outcome, and what sensors are involved, the modules described above can be very useful for specific tasks. On an OBDII compliant vehicle, the worst thing to do is use a signal modifier to offset the MAP/MAF voltage to try and accommodate larger injectors. Your vehicles ECU police will figure it out, and take appropriate actions to neutralize the threat!

The iEMS3 “Integrated Engine Management System 3”

Features & Benefits:

- Manifold pressure and RPM referenced fuel calibration.
- Manifold pressure and RPM referenced ignition timing calibration.
- Internal 2.5 bar pressure sensor.
- Analog input from external 0-5V sensors (allows utilization of stock sensors for reference input).
- Analog output voltage limit function (useful on forced induction using stock MAP sensor).
- Allows for the use of significantly larger fuel injectors while retaining proper air / fuel ratios.
- Individual cylinder fuel trim.
- Internal injector drivers operate high resistance fuel injectors, while using external resistors will allow the IEMS3 to run low resistance injectors.
- Smart Card programmable. No need to link to IEMS3 to make program changes.

• Allows for stock-like drivability on heavily modified engines.
• Programmable RPM limit.
• Utilizes factory ECU adaptive capability to properly adjust for various operating conditions, such as altitude, engine coolant temperatures, intake air temperatures, etc.,
• Programmable output signal(s) (12V- negative) can be used to activate a switched component or PWM (pulse width modulation) controlled component.
• Plugs into factory injector wiring harness for easy installation.
• Does not alter other stock ECU functions, allowing for full OBD2 functionality.
• Full data logging system with graphical screen.
• 3D mapping view of IEMS3 fuel and ignition programs.
• Active fuel and ignition cells are highlighted in the IEMS3 software while linked to the system in the logging mode.

The IEMS3 system allows precise tuning of the air to fuel ratio and ignition timing over the entire operating range of the engine. Simply inserting a pre-programmed Smart Card immediately changes the program settings for the current driving situation or octane of fuel as desired.

The unit contains its own fuel injector drivers and is wired in between the factory ECU and engine. It is especially useful for recalibration of both forced induction engines and those with extensive modifications, allowing the tuner to quickly get the engine running correctly. The IEMS3 is similar to a stand-alone engine management system, but also has similarities to a piggyback system. We consider it as working “in series” with the factory ECU.

In a true stand-alone system, you must program for every operating condition the engine will experience, such as load, throttle position, RPM, engine temperature, air temperature, etc. These systems can be quite complex to tune. Most ECU’s also control radiator fan operation, A/C operation, emissions operation and diagnostic functions. Stand-alones are generally not compatible with OBD2 emissions testing in that they replace the factory ECU and will not link up with state run emissions equipment. These systems are best suited for racetrack use where engine tuners can fine-tune the program to the environment of the moment for optimal performance.

In a typical piggyback system, control over the engine is done by manipulating inputs to the stock ECU. Manifold air pressure and oxygen sensor voltages can be altered in order to make the ECU change its load calibration, thus altering fuel and ignition advance curves. Reducing MAP sensor voltage has the effect of reducing injector pulse width by making the ECU “think” the engine is under greater vacuum than actual. At the same time, ignition timing is advanced due to the ECU believing the engine is under a lower load. Conversely, increasing voltage has the opposite effect, increasing fuel and reducing timing advance. When tuning with systems of this type, you can find yourself in situations where you can have proper part throttle tuning, or

proper full throttle tuning, but rarely both if the engine is heavily modified or has forced induction.

The IEMS3 offers the best of both worlds. Stand alone system control, but with the simplicity of a piggyback system. The IEMS3 controls fuel and timing, leaving the stock ECU to handle all other functions, such as idle speed, A/C control, emissions operation, etc.

System Description:

The IEMS3 uses the factory ECU injector pulse output as a timing reference, which can be scaled within a range of 0% to 199%. This is beneficial in that if you're using larger injectors, you can use a calculated percentage of the stock ECU pulse to make the larger injectors flow the same as the stock ones. This allows the engine to start up and immediately operate with the proper air/fuel ratio in closed loop operation. For use under a heavier load (full throttle / boost), you can create a fuel curve that begins adding milliseconds of injector pulse width as the load / boost increases.

The fuel curve can be further trimmed based on the engine RPM, since the engine efficiency / fuel demand can change with RPM. Negative values can also be placed in load and RPM tables, allowing you to shut off injectors under deceleration and trim down fuel when it is otherwise too rich (both very beneficial for naturally aspirated engines)

Ignition timing can be controlled for retard and/or advance depending on the vehicle make and model. See additional discussion as to when ignition can be advanced. The curve can be configured based on engine load and RPM. The factory ECU continues to drive the coils, though the input and resulting delivered spark advance is controlled by the IEMS3. In places where the factory programmed timing curve was too advanced for an engine, such as under boost, it can be retarded, while leaving normal timing in vacuum conditions. In some cases, you can also add timing advance in areas where the factory programmed timing advance was insufficient, such as for naturally aspirated engines.

The IEMS3 has programmable 12V negative outputs. The output can be used to operate a relay, turn on a shift light, operate a PWM injector circuit, etc. The output is signal (manifold pressure or voltage) and engine RPM referenced. For example, you can create a program which will turn on a Nitrous relay, increase the injector pulse and decrease the ignition advance all at the same time.

For use on engines that pressurize the stock intake manifold, the IEMS3 has a programmable analog output signal limiting function. This allows the MAP sensor signal to be processed by the IEMS3 before going to the original equipment ECU. The tuner can adjust the maximum allowable voltage that will go out to the stock

ECU in an RPM referenced table, keeping check engine lights from occurring due to the ECU seeing a MAP sensor voltage higher than normal when under boost.

The different fuel and timing programs are written using the IEMS3 software. Program files can be modified, saved, e-mailed and written to Smart Cards with serial and USB plug reader / writers. The IEMS3 has an internal Smart Card reader and writer. To change the program, simply slide the card into the slot and wait for the green ready light to blink (typically 1-2 seconds). Using Smart Cards allows you to quickly change the program without having to link up to the IEMS3. You can have an unlimited number of Smart Card programs (they are rewrite-able) and they are compact enough to put in your wallet.

When tuning, there are numerous factors that work together to produce proper engine operation and maximum power. This section is not meant to replace the many books on engine tuning and the years of experience most professionals have. Rather, it is simply an introductory guide for using the iEMS3.

The IEMS3 system and software does not have built in safeguard settings. It is possible to fine tune a vehicles operational envelope as well as create settings that would be detrimental to engine operation. Always double check and verify your changes. It is strongly suggested that you save your files with a logical name for easy recognition. For example it is much more desirable to name the tunes “91 octane”, 93 octane”, and “Race fuel”, rather than “Tune 1, 2, 3”. You can clearly tell which file you are loading.

Special tools will be required for fine-tuning, such as a scan tool and A/F ratio logging system. These items are readily available through various suppliers (most dyno’s have A/F ratio monitoring equipment). See the section discussing Tuning Tools.

Ignition timing and fuel delivery work together. A change in one has an impact on the other. For example, an area at full throttle where the A/F ratio may be too rich may indicate too little spark advance rather than too much fuel pulse (lighting the fuel later does not allow as much of it to burn in the combustion chamber, hence there is more unburned fuel in the exhaust). In an area like this, you may either reduce fuel injector pulse or increase spark advance.

Increasing the spark advance will generally increase the power as more fuel is burned and its energy is released in the combustion chamber. The fuel octane and cylinder pressure are usually the determining factors of how far you can increase the spark advance before pre-ignition / detonation occurs.

Higher-octane fuel is harder to ignite, so it can generally take more spark advance. Other factors, such as piston construction should also be taken into consideration. When tuning on a forced induction engine, transitions from vacuum to boost play an important role in vehicle drivability. In the case of a positive displacement

Supercharger, boost can come on very fast and at a low RPM. The factory ECU was not originally programmed for such engine load changes so quickly. This means that we must go deeper into the engine vacuum table when making our spark advance and fuel calibrations, in order to stay in front of the factory ECU curves.

True millisecond fuel values for each load and RPM, versus the use of “VE Tables”.

Engine management systems with VE tables, have fuel values entered as a percent (%) instead of milliseconds (ms). A VE Table percent value (%) basically follows the torque curve and is less dependant on MAP sensor load. If we divide the iEMS3 fuel ms value with MAP-load value, you get a VE (%) value.

For simplicity in use by the end user, it was deemed that using a factual value (ms of fuel pulse) would be easier to grasp than dealing with an imaginary number (% value). The difference is that it is easier to understand exactly how much fuel is being delivered when expressed in ms rather than a % value of available injector fuel.

There is no difference in performance as the outcome is the same. If we have sufficient requests, we may issue a version of the software that expresses the fuel table in VE % values.

Fuel basics

There are different optimal AFR settings for different applications and loads. During light load cruise, most engines prefer a 14.7:1 air / fuel ratio. Under heavy load, a naturally aspirated engine may perform best at 12.9:1, while a forced induction application can range from 11.5:1 to 12.5:1 depending on the air charge temperature (sometimes fuel is used to cool the air).

In relation to ambient temperature, normally, the IEMS3 itself does not need to use temperature input. It uses the offsets of the stock ECU to compensate for temperature. The stock ECU has been properly programmed at the factory to decrease its injector pulse output (which the IEMS3 references) as air temperature increases / density decreases.

However, for forced induction, you may need to apply a temperature offset to reduce the load on closed loop adaptives, and when in open loop, to automatically add or reduce the injector pulse width to eliminate the need to create multiple maps for varying conditions. The Generation 3 unit has this compensation ability included in the available options for fuel. For example, a tune for 40 degrees F may need 5% more enrichment than the tune for 100 degrees F

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There is a finite amount of time available to inject fuel into a cylinder while the intake valve is open. Generally, you have 20ms of injector pulse time available at 6,000 RPM. At 3000 RPM, you would have twice the amount of time available (40 ms available at 3,000 RPM).

Injectors also have duty cycle limitations, which refers to how long an injector is pulsed relative to the amount of time available. If you pulsed an injector 20ms at an engine RPM of 6,000, you would be at 100% duty cycle. If you pulsed the same injector 20ms at 3,000 engine RPM, you would be at 50% duty cycle. To inject more fuel than the time available, you will require larger injectors as their spray can produce greater volume in the same amount of time. Normally, factory ECU programming limits duty cycle to 80% at maximum RPM. Beyond 80% decreases injector life span, and the closer to 100% the duty cycle approaches, increases the risk of the injector sticking open. 100% duty cycle should only be used with extreme consideration, and never for primarily street driven vehicle.

Timing basics

When setting up the spark advance curves, there are many factors that are involved. When performing timing changes, the compression ratio, fuel octane, camshaft profile, cylinder head design, etc. must all be considered. Generally, there is considerable power to be gained by optimizing the spark advance. On the flip side, you can get spark knock if you ignite the fuel too early, which can cause damage to the engine. The iEMS3 can only advance the ignition in certain applications. Review the discussion regarding timing setup for timing limitations. If the engine has forced induction or Nitrous Oxide, you will want to start by reducing the timing advance under boost / NOS use.

TOOLS for TUNING:

Tuning cannot be done without the necessary measurement tools. You will need some basic tools to tune your engine. For tuning in CLOSED LOOP mode, you will need a scan tool that will allow you to interface with the stock Engine Control Unit (ECU). A scan tool provides information regarding when the ECU is in OPEN LOOP or CLOSED LOOP mode and what the FUEL TRIMS are.

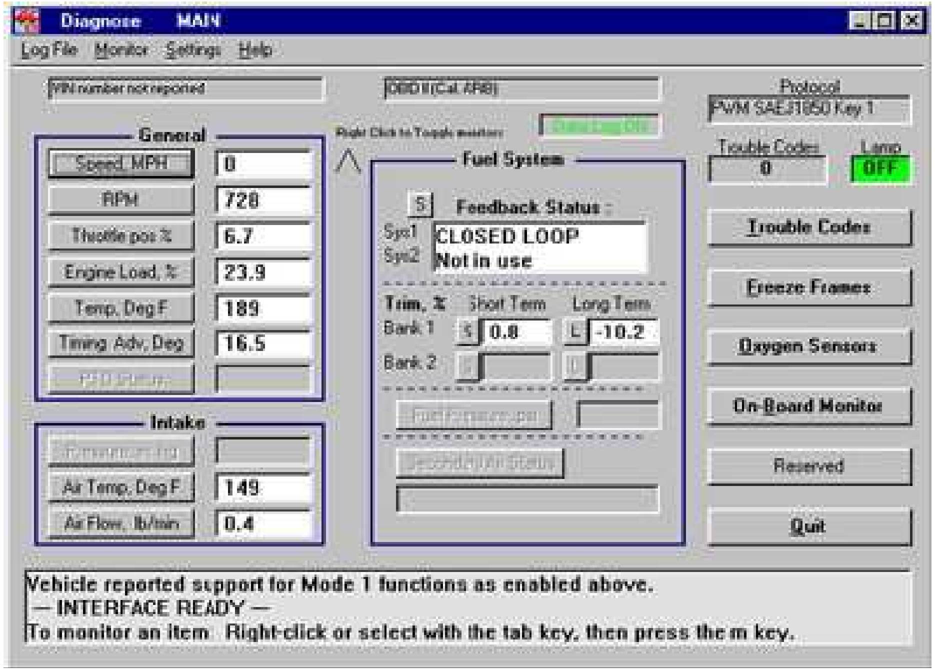
For tuning in OPEN LOOP mode, you will need a wideband sensor and controller. The wideband unit will provide you with the critical air/fuel ratio information.

Scan tools simply report out the status of what is going on in the ECU, speed of refresh rate is the primary factor when shopping for a scan tool, but you should always limit the parameters monitored to the Closed/Open loop state, and short term/long term trims. This will ensure the fastest refresh rate for the data.

A wideband controller/sensor package is a more expensive item. Your AFR is one of the most critical parameters to monitor, so skimping on quality here can have a

big effect later on. I don't like to get into brand discussions, but I will say that if you are considering the Innovative line, I like the LM-1 handheld, I do NOT like the LC-1 remote gauge unit. The LC-1 has been very troublesome in its use for us. If you want a gauge mount based readout, look into a PLX or other top brand unit.

Scan Tools:



This is the main page from the BR-3 OBDII scan tool.

There are numerous scan tools on the market, some below $100.00, to professional units costing thousands of dollars. If you have an aftermarket handheld tuner such as SuperChips or Diablo, then you already have the ability to interpret the OBDII data and see what is taking place in real time regarding the fuel trims. The MSD Dashawk is a small readout unit, where as the Auto Enginuity unit uses software and a Laptop computer.
The scan tool connects to the OBD diagnostic port on your vehicle. It is normally located under the dash on the driver's side.

Wide Band Sensor Display Unit:

The Innovate Motor Sports LM-1 Wide Band Unit with data logging.

The wideband sensor is an advanced oxygen sensor that reads the oxygen content of the exhaust and reports the information to you with a digital display showing the air/fuel ratio of the mixture entering the engine.

If possible, install the sensor in the exhaust so it can sample the exhaust gas BEFORE the catalytic converter. This provides the most accurate reading of what the air/fuel ratio reading really is. The catalytic converter will alter the oxygen content of the exhaust and throw the reading off a slight amount.

If installing an O2 sensor, install it from the 9 o'clock to the 3 o'clock range. Never at the 6 o'clock position as condensation in the exhaust will damage the sensor.

Data Logging:

Data logging is a feature that you will want to look into when considering a wideband AFR unit. If you feed the wideband controller's aux 0-5volt output in to the IEMS3, you can easily datalog the AFR along with the other monitored engine parameters.

The purpose of data logging is to capture information that will assist you in identifying specific areas in your fuel/timing maps that need adjustment for better performance. A printout from a chassis dyno is a three-channel data logger. It simply logs horsepower/torque, RPM and Air/Fuel Ratio (AFR). The manufacturer of your AFR unit will have additional information related to this topic.

The Chassis Dyno:

Your vehicle should be road tuned before you even think about dyno tuning it. This does not mean that you have to be a terror on the road either. You are looking to get the tuning down in the vehicles everyday performance envelope. 0-80 mph will cover nearly the entire area where most people have drivability issues.

Most chassis dynos are inertia based, units like DynoJet, are generally only useful for tuning at full throttle. You MUST, completely road tune your closed loop map before you dyno tune full throttle on an inertia dyno.

If your shop uses a loading type dyno, then the dyno can very closely simulate real world road conditions and easily verify and tweak the closed loop tuning. This is because the dyno applies variable levels of resistance that can be held constant, to the turning of the rollers, and is not relying solely on the weight of the rollers for the applied load. Generally an Eddy Current load brake is used to apply the load. These are the types that the manufacturers use when developing the ECU programming, and the type used for emissions testing in many places.

Inertia style dynos will report a higher HP and Torque than a loading style dyno. Real world performance is what you are after, not maximum numbers on a dyno sheet. Make sure you are comparing apples to apples when looking at someone else's numbers as well.

We have found that the ECU's Closed Loop fuel map and its adaptive changes will have a slight affect on Open Loop (WOT), and how the ECU applies its internal fuel trims to the Open Loop fuel mixture. If you tune Open Loop (WOT) first and then go back and play with the Closed Loop, you will find that your Open Loop (WOT) AFR will change, and you may have wasted a dyno tuning session.

Another thing to watch out for is that your vehicle will perform one way on the dyno and then perform differently on the road. You can set the AFR that gives you max power on the dyno and then go out on the road and find that the AFR at wide open throttle is leaner. Tune the AFR on the dyno a little richer so that it will be in line with the desired on the street.

Dyno tuning should be used for verification and for the upper speed/rpm ranges that are unsafe for public highways.

ECU OPERATING MODES:

There are two primary operating modes that the stock ECU operates in, Open and Closed Loop. There is a third mode for deceleration where fuel will be cut for fuel economy and emissions. These three modes are what control the fuel mixture of the engine. The difference between two of the modes is whether or not the ECU is getting feedback from the oxygen sensors to make fine adjustments to the fuel mixture.

When the ECU is using feedback from the oxygen sensors to adjust the fuel mixture it is said to be operating in Closed Loop mode. When it is not using feedback from the oxygen sensors it is said to be in Open Loop or a Wide Open Throttle (WOT) mode. When the vehicle enters into an extended deep vacuum deceleration state, it is in the deceleration mode, and the ECU will cut nearly all fuel from the fuel mixture. This provides maximum fuel economy, the least emissions, and increases engine braking. This is normal function, and one we do not need to be concerned with

With a wideband connected, don't be surprised to see your AFR go to 19, 20 or more during decelerating. It is normal and not cause for alarm as it will return to normal AFR's after a period of time, or as soon as the pedal is moved even the slightest amount.

Closed Loop Mode:

The stock ECU uses fuel lookup tables to determine how much fuel to inject into the engine. It uses sensor inputs from; RPM, throttle position, MAP or MAF sensor values, intake air temperature, engine coolant temperature, even fuel pump voltage to determine just how much fuel by weight to inject into the engine. This initial amount of fuel is then fine-tuned based on the reading from the oxygen sensor. The adjustment it makes to the standard lookup tables is called fuel trim. Whenever the ECU is making these fine adjustments to the fuel mixture using feedback from the oxygen sensor, the ECU is operating in the Closed Loop mode.

When operating in the Closed Loop mode you do not have control over the fuel mixture. If you try to change the MAP/MAF sensor signal value to make it run richer or leaner, the ECU will just trim the fuel to keep the mixture near the preset 14.7:1 air fuel ratio by weight. **It is very important that this is clearly understood.**

For the most part you cannot change the mixture while the ECU is operating in CLOSED LOOP mode. If you try the ECU will resist keeping the mixture where it thinks it is supposed to be. There is a limit to how much control authority the ECU has to adjust the mixture. If the maximum fuel trim limit is exceeded and the ECU looses control of the mixture in CLOSED LOOP mode it will set a check engine light. You must work with the ECU when tuning CLOSED LOOP and not against it. The ECU will win every time.

What you can control in CLOSED LOOP is the amount of trimming the ECU has to perform, and the O2 sensor signal to the ECU. You will enjoy the best drivability when the fuel trims are minimized throughout the CLOSED LOOP region.

Open Loop Mode:

When the ECU is not using feedback from the oxygen sensor to adjust the mixture it is operating in OPEN LOOP mode. When you first start the engine, it will start up in OPEN LOOP mode because the oxygen sensors have not heated enough to start the chemical reaction needed to provide a usable signal. Under some conditions during deceleration with the throttle closed it will switch to OPEN LOOP, and finally, when the throttle is advanced to some preset point, usually around 80% or higher, or held at a high throttle position for a given time, the ECU will switch to OPEN LOOP mode and apply enrichment of the fuel mixture.

The important thing to know is that when the ECU is operating in OPEN LOOP mode it has no idea at all what the mixture is. It can be richer than it needs to be killing power and damaging the engine and catalytic converters, or way too lean causing serious engine damage in a short period of time. It is OPEN LOOP tuning where you can unlock hidden power or destroy your engine very quickly.

Fuel Cut:

A third ECU mode is called Fuel Cut. The ECU will cut fuel to the engine in three conditions. The ECU will cut fuel to the engine when you attempt to exceed the maximum safe engine RPM to protect the engine. It will cut the fuel to the engine if you attempt to exceed the maximum safe tire speed rating programmed into the ECU (with electronic throttle control, the ECU will likely reduce power through manipulation of the throttle blade opening rather than fuel cut in this situation).
It will also cut fuel to the engine if you are decelerating with the throttle closed, generally above 1500 RPM.

When tuning you are most concerned with deceleration FUEL CUT. You want to make sure that the ECU makes a smooth transition from FUEL CUT deceleration back to CLOSED LOOP, or to a CLOSED LOOP idle if the vehicle is stopped. If you have your closed loop tuning nailed and have limited the amount of fuel trimming taking place, then deceleration transition will be smooth.

It is important to realize that this is a normal function, and not something to be concerned about. I have had customers call in a panic because they were monitoring their AFR (smart thing to do), and were seeing the AFR go to 20 upon deceleration. Remember this is normal, and the engine is not under any load, it only needs enough fuel to keep it running.

But, one thing he did do, and it is never a good thing, he kept repeating it 15 or 20 times and it was always the same. While in this situation, there was no impact by this, if you see something out of the ordinary, it is not a good idea to keep repeating it hoping it will go away. The issue most likely will remain, but your engine may decide to go away! Call and discuss the issue with a knowledgeable individual and get it dismissed or resolved. If you kick your toe on a chair, it hurts, you don't need to do it 10 more times to verify that "Yes" it did hurt.

TUNING (Not Yet!):

The very best way to start your tuning is to learn how your vehicle operates while STOCK. Before you start making substantial modifications and installing larger injectors, fuel pumps, and engine tuning, take some time to learn how your vehicle operates.

Hook up the scan tool and wideband unit, drive the vehicle normally and monitor the fuel trims, air/fuel ratios, and most importantly how the ECU switches from OPEN LOOP to CLOSED LOOP operation.

A few of the troublesome areas are how it transitions from OPEN LOOP cold and hot starts to CLOSED LOOP idle, and how it transitions from OPEN LOOP deceleration and stopping to CLOSED LOOP idle.

Generally you want it to function just like the stock operation in these areas. By observing these things before you start modifying your car, you will learn valuable information and greatly speed up your tuning time. However,
most people install everything first, and then try to figure out how to tune it, or hope it will not need tuning. A reality check is needed in that case.

Maintenance FIRST!

Before you even start on your vehicle, you should perform some routine maintenance checks;

- Verify that the throttle body plate is opening all the way when the accelerator pedal is put to the floor (if electronic throttle control, this is not possible, but you can pull the inlet tube and check for free range of travel (MOTOR OFF!). If it is not functioning properly, the engine will not make full power, and it will delay the ECU switching into OPEN LOOP mode.

- Inspect your exhaust. It must not in the area ahead of the catalytic converter. If it leaks here, it can cause faulty readings by the oxygen sensor and your wide band unit and can really confuse your tuning efforts. If you have erratic fuel trims this is one thing that is a likely culprit.

- Make sure ALL of your vacuum lines are in good condition with NO leaks. You would be surprised how many vehicles are sold cheap because they have a “serious” problem that turns out to be an old cracked vacuum line. If over 5 years old, I would be installing new lines as they do age.

- What is the overall health of the engine? If there is oil coming out of the engine breather, smoke out the exhaust, or general state of disrepair, the engine might be on its last leg. If you are a tuner reading this, you do not want to be the one operating or tuning it when it comes apart. It will always be your fault.

- Check the engine oil. If it is low or looks really bad, think twice about tuning the vehicle. Poor maintenance is a sure sign of lurking issues.

- Verify the air inlet is secure and leak free. If the vehicle has a MAF sensor, and air is allowed to enter the engine that does not go through and get read by the MAF sensor, you will have a very long and frustrating tuning session.

- Verify O2 sensor function with a scan tool. Check the waveform and make sure it nice and healthy. An old or defective O2 sensor will result in poor CLOSED

LOOP operation that maybe very erratic. If in doubt, replace the sensors, they are a cheap investment for success.

- Check the air filter and the MAF sensor if the vehicle has one. If the filter is filthy, replace or clean it. You want to check the MAF sensor for oil contamination and most have a screen over them, look for the obvious debris obstruction to air flow. If it is dirty or flow is obstructed, it will throw your tune off and cause erratic operation. The MAF sensor can be cleaned with non-residue electronic parts cleaner (NOT carb or brake cleaner, go to Radio Shack, not the auto parts store!

  When using a filter that is recharged such as a K&N or AIRAID, be sure to use a minimum of oil to avoid contamination of the MAF sensor element. You want your vehicle to be in the best condition possible prior to performing major modifications. This helps to ensure that any potential problems are identified up front (and corrected), and clears the way to see the maximum gains from your efforts.

Ready for Tuning (almost!) Learning the iEMS3:

If you haven't already, and before you go any further stop and locate the technical repair manual for the vehicle (not the owners manual) And the manual that came with your tuning device installed on your vehicle. Read it completely so you have a clear understanding of its operation. Now, read it a second time to pick up the items you just skimmed through.

Taking a little time here could save you a lot of heartache down the road from a very costly mistake.

Installing the iEMS3 Software

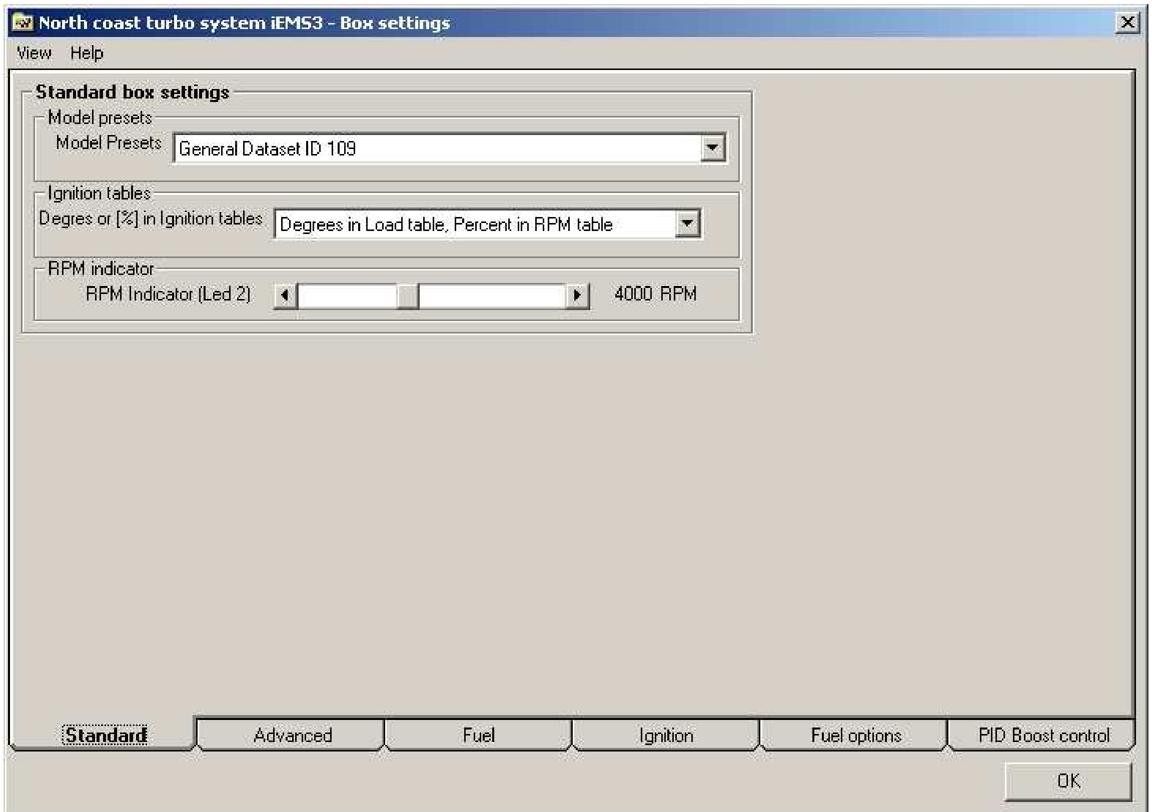
Put the CD in your computer and start the installation by double clicking the file setup.exe. Then just follow the instructions. If you have downloaded the file from www.iems3.com then you must first unzip the downloaded file using winzip. This program is available at www.winzip.com

Upgrading the iEMS3 Software

Upgrades are made available at www.iems3.com download and follow the instructions.

Lets get started tuning the vehicle. The first thing to do is the initial setup of the tuning software. Open the iEMS3 Tuning software in your Windows PC and follow the prompts for installation:

iEMS3 box settings – Standard Tab



Model preset

Dataset is a basic setup of the iEMS3 software in order to determine which functions, controls, menus and tables are to be available. This is to simplify for the user and not show more controls than necessary.

Dataset ID

This is an identification number (103-109) which specifies which type of TuneCard is used. This is also co-ordinated with the IEMS3 box firmware version. It's not possible to use a different Dataset ID in the IEMS3 box and on the TuneCard.

Swap degrees and percent in ignition table

This gives you the option of switching the load and rpm-table units (degrees and %). This is up to the individual tuners taste that determines what is best to use. It only has relevance if you intend to tune the ignition.

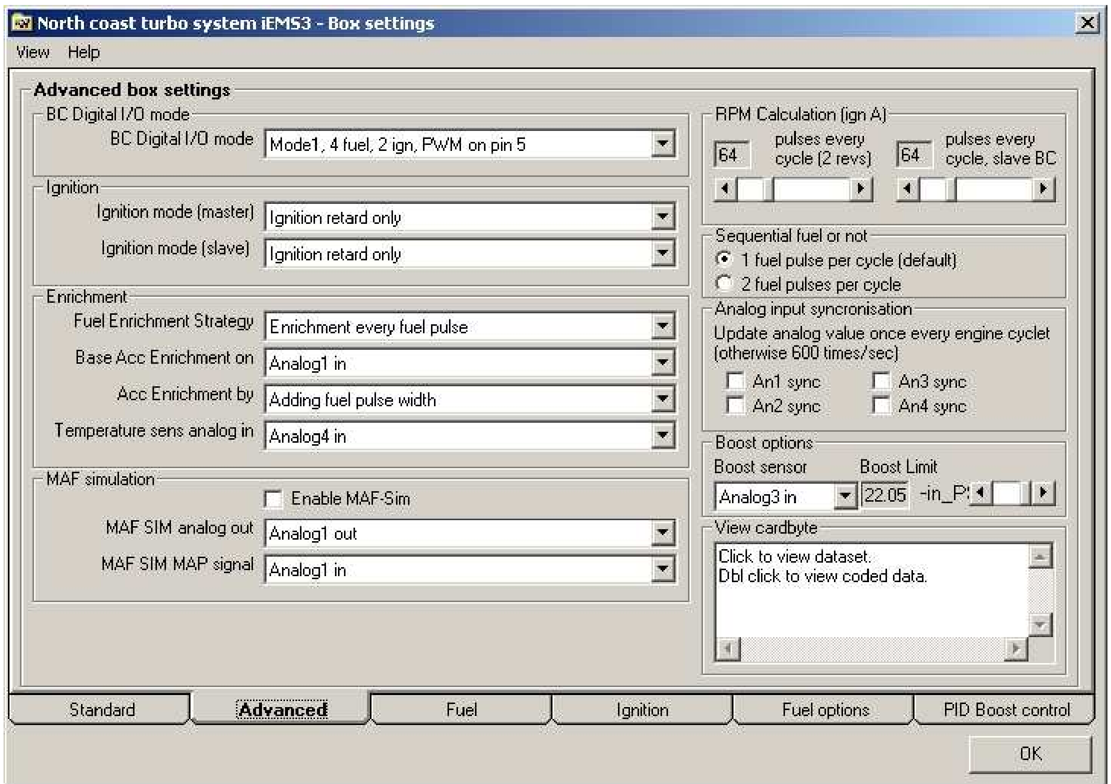
Fuel RPM Table Precision

This gives you the option of increasing the number of fuel rpm cells to tune (every 250rpm). In this case it will not be possible to use the Analog2 output.

RPM indicator (LED2)

Use this to select the rpm at which the red LED on the front panel will light up.

Advanced Tab



Enable By Pass mode

Used to let all input signals pass through the IEMS3 box without being altered. This will be the same as using the mechanical bypass plug.
This only works in the following case:

- Boost control must be connected to PWM In/Out pins 11-12 and be run in Mode5
- The use of Dataset ID 106 or higher

What actually happens is that all tables are zeroed, the PID regulation is deactivated and the program runs in mode1. This means that all signals will pass through the IEMS3 box without being altered.

iEMS3 digital I/O mode

This is where the main mode of operation is determined and which connector pins are used for the various features and functions. In the Ignition load, Fuel load and PWM load tabs, you will specify which analog input is to be used to measure load or to base the tuning on. If the engine has a MAP sensor, you will specify which pin this is connected to; other engines may want to base the tuning on the throttle position sensor.

Digital inputs and outputs

The IS4G3 has 6 digital in/output-pairs (12 pins)(IS8G3 has double), where every input has its associated output. These are called: Fuel A-Fuel E(5 fuel channels), Ignition A-Ignition B (2 Ignition channels) and PWM (1 boost channel). One of the signal-pairs can be used for different functions and cannot be used simultaneously. This is Fuel E, Ignition B and PWM.

The reason for organising the in/outputs in pairs is that when connecting a bypass-plug (instead of the IEMS3 box) then all channels will be inter connected and the signals are unaffected (the engine behaves stock). When the IEMS3 box is connected, the box will modify the signals according to the Tuning parameters and send them to the paired output.

iEMS3 digital I/O modes

The IEMS3 box can thus be run in different modes where the pins have different functions:

- Mode1
    - 4 Fuel in/out, FuelA-FuelD, pins 15-22
    - 2 Ignition in/out, IgnitionA-IgnitionB, pins 11-14
    - Boost control out, PWM_OUT, pin 5

- Mode2, no longer activated

- Mode3
    - 5 Fuel in/out, FuelA-FuelE, pins 15-22 & 11-12
    - 1 Ignition in/out, IgnitionA, pins 13-14
    - Boost control out, PWM_OUT, pin 5

- Mode4, no longer activated

- Mode5
  - 4 Fuel in/out, FuelA-FuelD, pins 15-22
  - 1 Ignition in/out, IgnitionA, pins 13-14
  - Boost control in/out, PWM_OUT/IN, pins 11-12

Digital out

The IS4G3 has one pure digital output (IS8G3 has two), PWM_OUT which in mode1&3 is used to control the boost, but in mode5 can be used for other purposes.

Analog inputs and outputs

The iEMS3 has two analog in/output pairs where every input has its associated output. These are called: Analog1 and Analog2. The basic idea with this is to limit the analog sensor signal (rpm dependant)l to a value which represents the stock manifold pressure or Mass airflow. In the iEMS3 software, you will select which analog sensor signal to base the tuning on. This selection is done at pages: Ignition load, Fuel load and PWM load.

Analog input

The iEMS3 has one more analog input which is a pure input, thus the total is 3 analog inputs (4 cyl has 3, 8 cyl has 6).

Ignition Mode master

Setting used to specify if the ignition can only be retarded or both retarded and advanced

Ignition Mode slave

Setting used to specify if the ignition can only be retarded or both retarded and advanced. The slave setting is only relevant with the IS8G3. This IEMS3 box has two PCB cards where one is the master and the other the slave.

Fuel enrichment strategy

Setting to specify how the acceleration fuel enrichment pulse is to be applied; Add acc pulse to all fuel pulses or only to one fuel pulse per engine cycle. If choosing “add to all fuel pulses”, sometimes this will result in too much fuel as the ECU sometimes generates more than one fuel pulse per engine cycle, typically during acceleration.

Base Acceleration Enrichment on

Selects the analog input to base the IEMS3 box generated acceleration fuel enrichment on (in the case such is used).

Acceleration Enrichment performed by

Selects if the acc fuel pulse is to be generated by quickly increaseing the MAP sensor signal (and thus stimulating the ECU to generate the acc pulses) or by letting the IEMS3 box generate the acc pulses.

Enrichment

When MAF simulation is active you have to control acceleration fuel enrichment. This is done by setting which sensor the enrichment is based on. In this case it would be Analog3, which is the accelerator pedal (or TPS sensor).

Enable MAFSIM

This activates the Mass airflow simulation. When the engine has a stock Mass airflow sensor this can be removed and the signal to the ECU is generated by the IEMS3 box with the help of an internal MAP sensor.
This deactivates all other previous tuning for Analog1/2 output.

MAF SIM analog out

Selects which analog output is to generate the simulated Mass airflow signal. This signal must then be connected to the ECU.

MAF SIM MAP signal

Selects which analog input is used to measure the MAP signal. The internal MAP sensor is always connected to Analog3.

MAF SIM limit

Indicates if the simulated MAF-signal should be limited. If this would be the case the MAF-SIM limit table is used. This also makes the Analog2-table inactive.

RPM Calculation

The IEMS3 box **always** uses Ignition A to calculate the rpm. The signal can be from various sources though as long as we know how many pulses per rev is being generated. Both Ignition A and Ignition B can be connected to the cam and crank signals or the ECU driver signals to the ignition module. It's important that the signals are of 0V to 5-20V type. Some signals are too weak and must use an amplifier to achieve this voltage level.

To get the correct rpm calculation you must specify how many pulses per engine cycle (not engine revs) are present at Ignition A. If a slave is connected (IS8G3) then the correct value must be entered in the right control as well.

Analog input settings

Specifies if any analog input channel that is being measured should be synchronised with the engine cycle. Sometimes it's an advantage to synchronise the MAP sensor if it is somewhat unstable. This could be an issue regarding ignition adjustment. Used If the MAP sensor output is spiky during high rpms, (High performance engines). The system should measure the MAP only one time per revolution, and always at the same point relative to the crank. The draw back of this is a slower measurement and response since the MAP (and fuel calc) is made only 1 time/revolution.

Boost options

Here you can select which analog input channel measures the boost. Normally this is the same as the MAP sensor (if installed). "Boost limit" is a safety feature where you can set a voltage level (corresponding to a certain boost level) above which the IEMS3 box tries to reduce the boost to the base level and at the same time releases all sensor limiting to allow the ECU to perform its own safety features.

View cardbyte

Can be used as an advanced debugger tool where you can view all tuning on the TuneCard. We do recommend that you rather use the Setting viewer for this purpose.

Ignition

3D ignition map size

Choose map size (number of cells in the ignition map)

- 18 rpm x 11 load
- 15 rpm x 13 load
- 11 rpm x 18 load

Base ignition load on:

Determines which analog input should be used to calculate ignition. “Analog X in minus Analog Y in” is used to base the calculation on the difference between two signals. A common example is to use Analog 1_in – Analog 1_out, if this is the MAP signal, and limit the output to the ECU. If the signals aren’t limited the output signal is the same as the input signal, the difference is then 0V. If you at a specific moment limit the signal from 4.5V to 3.5V the difference is 1V, you can then retard the ignition even more because the ECU can’t see the real signal.

Table control

You are free to select RPM and load points for the fuel map. Select which cells to modify and press desired button.

Increase

Increases selected cell. All the cells below automatically changes as well.

Decrease

Decreases selected cell. All the cells below automatically changes as well.

Insert row

Inserts a new row to make more tuning points in a specific area. This removes the last cell.

Convert map to new axis

If you’ve already done a tuning map it’s still possible to convert the map to a different number of cells or area of measurement. See page Fuel settings for more information.

Fuel

Base fuel load on:

Determines which analog input is used to calculate the fuel enrichment. “Analog X in minus Analog Y in” is used to base the calculation on the difference between two signals. A common example is to use Analog 1_in – Analog 1_out, if this is the MAP signal, and limit the output to the ECU. If the signals aren’t limited the output signal is the same as the input signal, the difference is then 0V. If you decide to limit the signal from 4.5V to 3.5V the difference is 1V, you can then provide fuel enrichment proportional to the difference. The ECU doesn’t see the pressure difference and because of this can’t compensate the fuel.

3D fuel options

3D map size

This is where you set how large the main fuel map should be.

Table control

You are free to select RPM and load points for the fuel map. Select which cells to modify and press desired button.

Increase

Increases selected cell. All the cells below automatically changes as well.

Decrease

Decreases selected cell. All the cells below automatically changes as well.

Insert row

Inserts a new row to make more tuning points in a specific area. This removes the last cell.

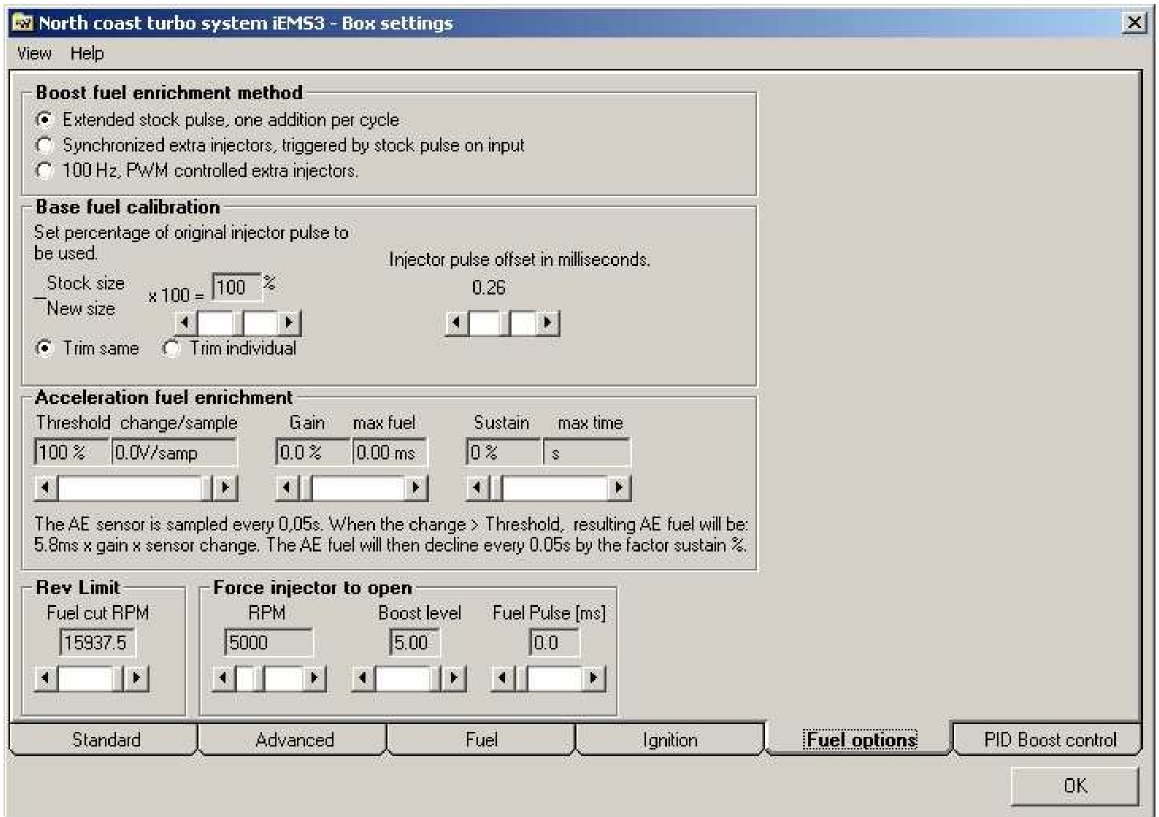
Convert map to new axis

If you've already created a tuning map it's still possible to convert the map to a different number of cells or area of measurement.

1) Start off by saving current map by clicking "Save current map". The current map is then saved in a new window
2) You can now change all the settings. (Change size, which rpm and load should be on the different axis, change MAP sensor etc)
3) Click "Convert saved map" and BCLab automatically converts the map and adjusts all the fuel cells.

Carefully check that the map was converted the way you intended. If you convert a map from 0-8000 rpm and decrease it to 0-5000 rpm the values are converted correctly. If you convert a map from 0-5000 rpm and increase it to 0-8000 rpm the iEMS3 converts the area 5000-8000 rpm with the same values that you had at 5000 rpm. This is the best guess the program is able to do.

Fuel Options



Boost Fuel Enrichment Method

Extended stock pulse

Enriches the fuel by extending the stock fuel pulse. This is the most common method.

Synchronized extra injector

When you use extra injectors to supply the fuel enrichment.

100 Hz PWM

Used when you don't want to synchronise the fuel enrichment with the rpm, but only "spray" fuel enrichment. This is not a method we normally recommend, it's normally better to use the “synchronised extra injector method”.

Base Fuel Calculation

There is the ability to compensate if you have installed larger injectors than stock. You can both compensate for different size and different opening times (percent and offset). You can even make the adjustment individually for each injector. Click "Trim individual" if you need to adjust individual cylinders fuel supply.

Injector size

Specifies stock injector size in relation to the new injector size. If you have doubled the size of the new injector the % value is 50%. This means that the iEMS3 will shorten all the stock pulses to half, to compensate for the double size injectors.

Injector offset

The offset value is a measure of how fast the new injector will open and close in relation to the stock one. This is most noticeable at low load (idle) when the injectors have a short pulse. If you know the exact specs of the stock and new injectors it's possible to calculate the offset but this is seldom the case. You are left to test this at idle to find the correct value. You can start by selecting 0 ms. It also compensates for the fact that if you half the injector pulses, the idle pulses may be below the time where the injector shoots fuel at all (typically 1 ms).

How to tune the Injector size and offset

First you specify the injector size relation. This will then make sure you have the”big picture” correct. This will make the engine run correctly on high load and at long fuel pulses. When you have the right fuel for full load, quite often the pulses on idle will be overcompensated so you have to add some offset fuel. Normally an injector starts to give fuel for pulses over 1 ms, so at 2 ms fuel pulses, the engine actually only get 1 ms fuel. If the stock idle pulses are 2 ms and you halve it with the injector size compensation, the engine will not get any fuel with only 1 ms pulses. By adding some offset (0.5ms in this case with double size injectors) you will be back on same idle fuel as before. These 0.5 ms will not affect the full load so much. Theoretically about 0.5/20=2.5%

Acceleration Fuel Enrichment

The IEMS3 box can also add acceleration fuel when performing a quick acceleration. This function is based on an analog input, usually the throttle position. The IEMS3 box measures the throttle position 20 times per second and can then compare the current position with the last one and thus detect a rapid throttle movement. Which sensor to use and which strategy to use is selected in Box-settings, Enrichment.

The acceleration fuel enrichment is controlled by three parameters, Gain, Threshold and Sustain. The actual result will be extended fuel pulse in ms or a voltage increase for the Mass airflow simulation, depending on the chosen strategy.

Gain determines the fuel pulse at a certain throttle movement according to : Acc pulse=Gain* [current TPS – last TPS]. This means that a larger Gain will result in a longer acc pulse.

Threshold determines the minimum throttle change required to generate an acc pulse. If you select this value as 255 there will never be any acc pulses.

Sustain determines for how long the acc pulse will remain. If the IEMS3 box detected an acceleration situation and calculated the first acc pulse to be 1 ms, then the next acc pulse will be 1 ms multiplied by the sustain value. So if Sustain is 50% the next acc pulse will be 0.5 ms, then 0.25 ms and so on. The Sustain value 255 equals 100% and 0 equals 0%. The value 0 means that only one acc pulse per event is generated.

Rev Limit

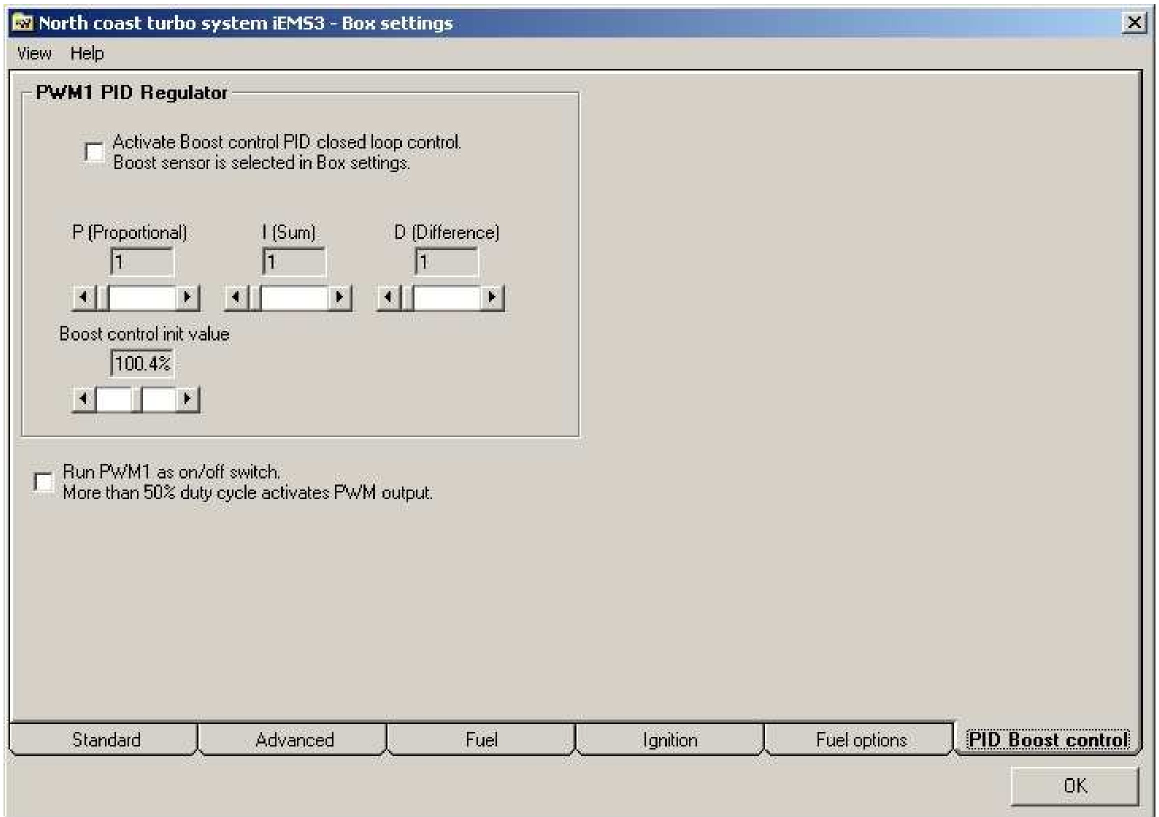
Fuel cut - Select an rpm when all fuel is cut off.

CAUTION: We do not suggest using fuel cut in boosted applications as in certain instances it could result in a severe lean condition in the engine.

RPM to allow open injectors & Boost level to open injectors

It's possible to force the injectors fully open when reaching a certain boost and at the same time be above a certain rpm. This is used to supply the maximum possible fuel.

PID Boost control

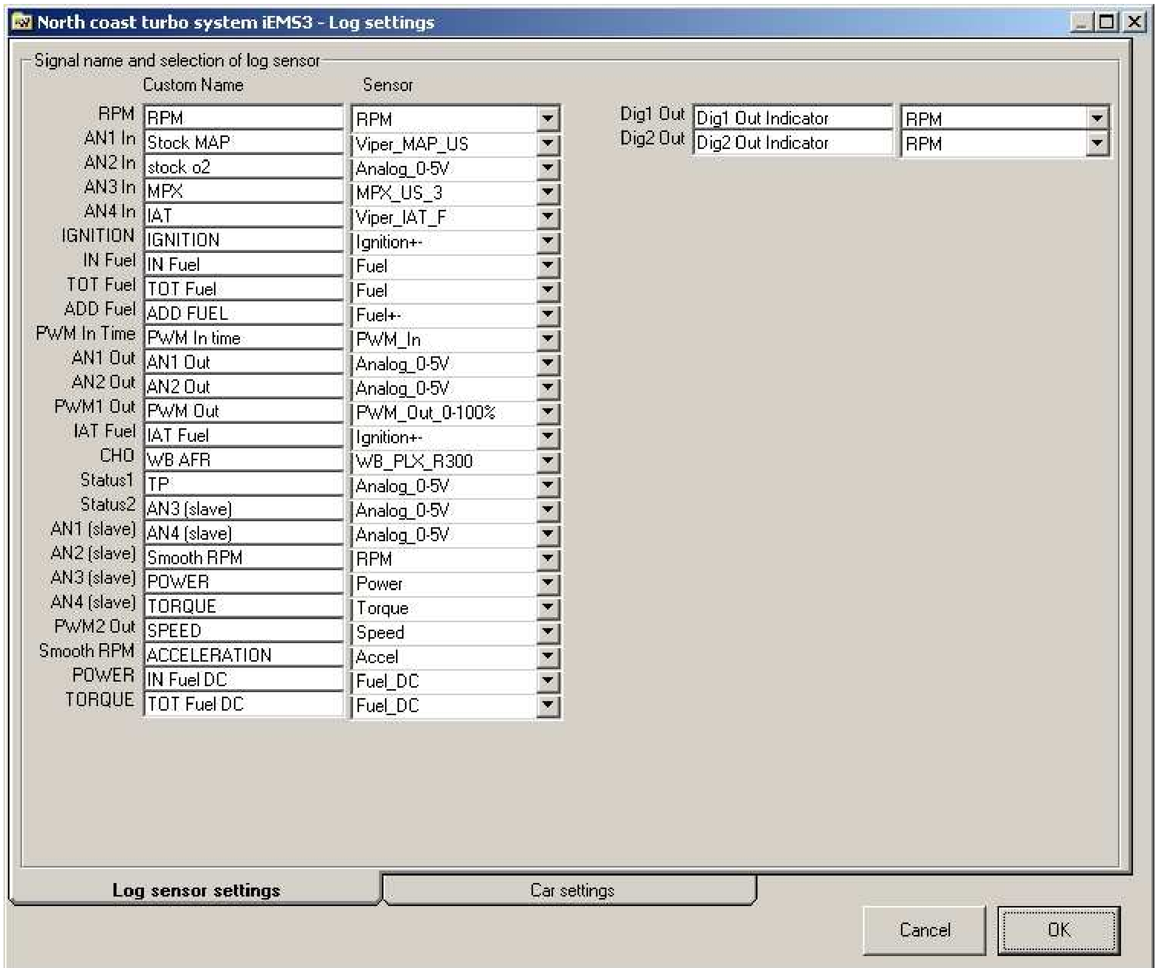


Advanced boost control will use feedback information to regulate the boost pressure. This is done with an advanced PID-regulation algorithm that controls the boost valve output signal depending on the boost pressure feedback signal.
The IEMS3 box measures the current boost feedback signal and compares this with the desired (tuned) boost level. If they are not the same there is an error present. If you open the throttle and the desired boost level rises then the regulating algorithm controls in which way that boost level is reached. If the boost level is too low, the signal to the boost valve will increase a bit and vice versa at too high of a boost pressure (called Gain or P-factor). If there has been an error for a longer time the boost valve output will increase a bit faster (Integration or I-factor). If the boost level changes rapidly the signal must be dampened in order to limit over boost and boost spiking for the boost not to pass the desired level. (Derivation or D-factor).

PWM output=Error*P + Long time error*I + Rate of change*D
The use of this function calls for knowledge in regulation theory and is not further addressed in this manual. More information and a manual are available from NCTS LLC.

See page PWM RPM for more info on how to enter values in the PWM_RPM table when using PID-regulation.

iEMS3 Log settings



Signal Name and Selection of Log Sensor

Normally the iEMS3 software will log 20 different signals. These signals have different names which you can see in the left column. In the second column you can chose your own names for the same signals. If you know the type of sensor the signals are you can specify this and the graphs will present the correct actual values. Also refer to Sensor specification for more info on this subject

Other Settings

Autosave

Selected if you wish the program to automatically save the log file after a log run. The name will be generated with date, time and the name selected in the lower textbox.

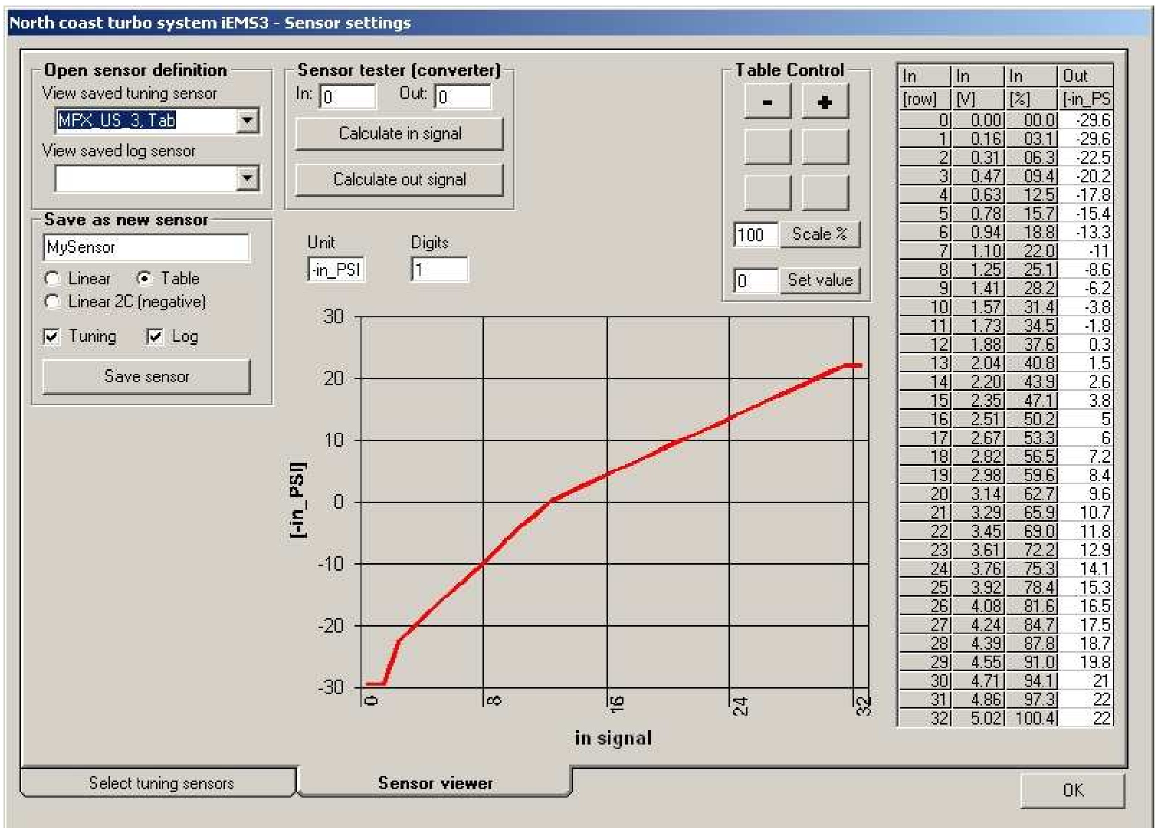
Default settings in log file

This gives you the ability to choose the default log settings when starting the BCLab software. It is controlled by the file Default_Logg_Settings.cbl which is located in the same folder as the BCLab program was installed in. This file is opened every time the BCLab is started. You can open this file as any other log file. Make the desired changes and save again.

Import default log sensors

If you open an old log file that doesn't have all the new log sensor definitions, you can set all the missing sensor definitions to the open log file.

iEMS3 Sensor viewer



In this section you can view, set and save all the sensor settings. Both log sensors and tuning sensors.
There are three types of sensors; Linear (2) and table entered.

Linear – Saved as a straight line that translates the voltage to a certain value.

Linear 2 –complement – Saved as a straight line but adapted to also be able to send negative numbers from the box to the computer. Typically used for ignition.

Table sensors – Saved in a 33 row table with 0.16V between the rows. You can change the data for every voltage which makes it possible to have nonlinear sensors such as temperature sensors etc.

If you know the voltage at various actual sensor values, this can be used in the program to display the actual sensor values (pressure, speed, gear etc) instead of the voltage.

Open sensor definition - You can open an already saved tuning or log sensor.

Save as new sensor - If you have redefined or created a new sensor this is where you save it.

NOTE! If you save the new sensor with a name from the list, then the old sensor definition will be changed.

Choose what kind of sensor you've created and fill in the right box.

Finally, you choose whether the sensor is a tuning sensor, log sensor or both.

The sensors used for tuning are saved in the ".ini" file and should be in the catalogue where you installed the program.

The log sensors are saved in each log file (xxx.cbl) and you choose where you want them on your hard drive. The sensors that are always there when you start the program are saved in a "default_log_settings.cbl" file and should be in the catalogue where you installed the program.

Sensor tester - A calculator for testing sensors by giving it a voltage or a desired data and calculate the other unit.

Linear control - To create or modify a linear or a linear 2-complement sensor you set two values along the line.

Table control - If you're using a table sensor this function helps you to freely modify all the values in the table. You're also able to modify the table by entering the values directly in the table.

Used Analog Sensors

You can connect many different sensors and transmitters to the IEMS3 box. Usually these are the cars original sensors. The sensor definitions translate the voltage to

the accurate unit that the sensors are supposed to measure e.g. temperature or pressure.

Used Analog Sensors for tuning - Choose what kind of sensor you connect to each of the analog inputs.

Chipdrive Status / USB Status / BC-box as TuneCard Reader Status

There are three ways to communicate with your box or TuneCards. In the upper left corner you will see the chosen communication mode. You may switch between these in the menu Edit-Toggle Interface or by pressing Ctrl+T.

- RS-232 serial communication between PC and BC-box
- Chipdrive connected to the PC that read/writes TuneCards
- Use of the BC-box as a TuneCard reader when BC-box is connected via RS232

Direct communication with the box

Handles the USB communication with the iEMS3.

Write - Saves the BCLab current tuning to the iEMS3

Verify - Verifies that the BC-box tuning is the same as the BCLab tuning

Read - Reads the BC-box tuning and displays them in BCLab

Info - Reads some general information from the iEMS3

Chipdrive reader

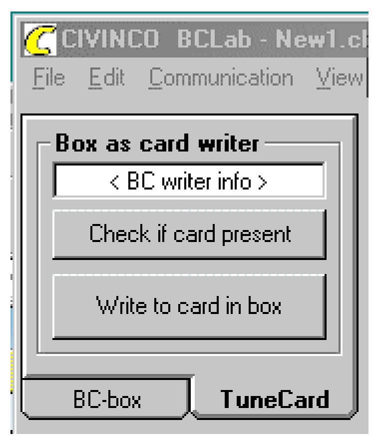
Handles TuneCard readers if connected to the PC. Currently supported readers are Chipdrive or Todos.

Find Reader - The program tests the connection with the Chipdrive reader

Write Card - Saves the BCLab current tuning to the TuneCard

Read Card - Reads the TuneCard tuning and displays them in BCLab

iEMS3 as TuneCard writer



Used when you want your PC-connected BC-box to read a TuneCard. This makes it possible to write TuneCards without the Chipdrive.

Check - The program tests that the BC-box works as a TuneCard reader

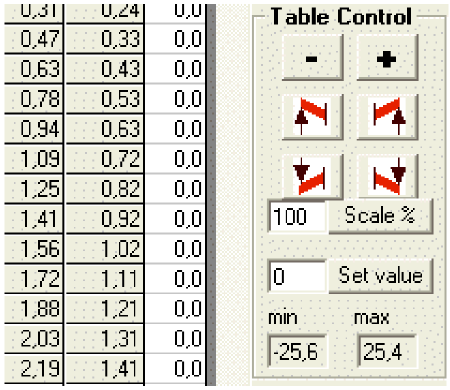
Write - Saves the BCLab current tuning to the TuneCard inserted in the BC-box

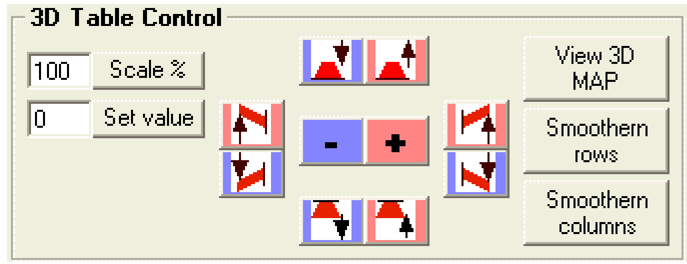
NOTE! When you put a TuneCard in the box it reads the current tuning on the TuneCard which might change the engine settings.

File Description

This area in the lower left corner can be used to write text to describe the new settings. The text is saved at the same time as you save the settings to the hard drive. They are not saved to the TuneCard or when you write to the box.

Table Control for all pages





All BCLab pages that have tuning tables also have a "Table Control" box or “3D Table Control”. This is used to easily adjust the tuning values in the table. You can also use this to edit several tuning values at the same time by marking the desired values. (to mark all table values click on "Deg" or "%" in the upper right corner).

- ”**+**” increase the selected values 1 step
- ”**-**” decrease the selected values 1 step
- increase slope of the selected values to the right
- decrease slope of the selected values to the right
- decrease slope of the selected values to the left
- increase slope of the selected values to the left
- decrease slope of the selected values in the bottom
- increase slope of the selected values in the bottom
- decrease slope of the selected values in the top
- increase slope of the selected values in the top
- "Scale%" Scales the marked values with the selected % value
- "Set to" Sets the marked values to the selected value.
- ”min", "max" Informs the user of the possible values in this table

You can also mark a cell and enter the value directly into the box without using the commands above.

Smooth data (interpolate)

There are two functions that evens out the values between cells, e.g. to get rid of the “highs and lows”. You can smooth the cells both vertically and horizontally.

Smooth Columns (interpolate)

If you have values in the first and last cells and want to fill the column cells evenly in between then you can mark the area and click “Smooth columns”

	0	500	1000	1500
0,13	2,02	2,02	2,02	2,02
0,21	2,02	2,02	2,02	2,02
0,29	2,02	2,02	2,02	2,02
0,36	2,02	2,02	2,02	2,02
0,44	2,02	2,02	2,02	2,02
0,52	2,02	2,02	2,02	2,02
0,60	10,0	10,0	10,0	10,0

Becomes

	0	500	1000	1500
0,13	2,02	2,02	2,02	2,02
0,21	3,1	3,1	3,1	3,1
0,29	4,5	4,5	4,5	4,5
0,36	5,8	5,8	5,8	5,8
0,44	7,2	7,2	7,2	7,2
0,52	8,6	8,6	8,6	8,6
0,60	10,0	10,0	10,0	10,0

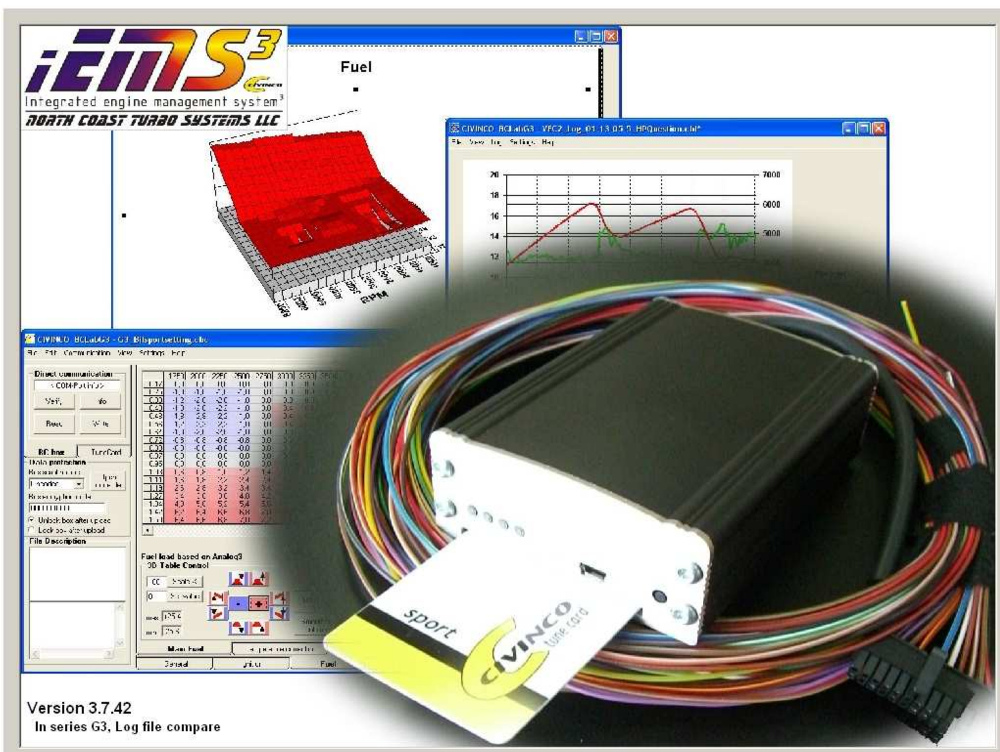
Smooth Rows (interpolate)

If you have values in the first and last cells and want to fill the row cells in between you can mark the area and click “Smooth rows”

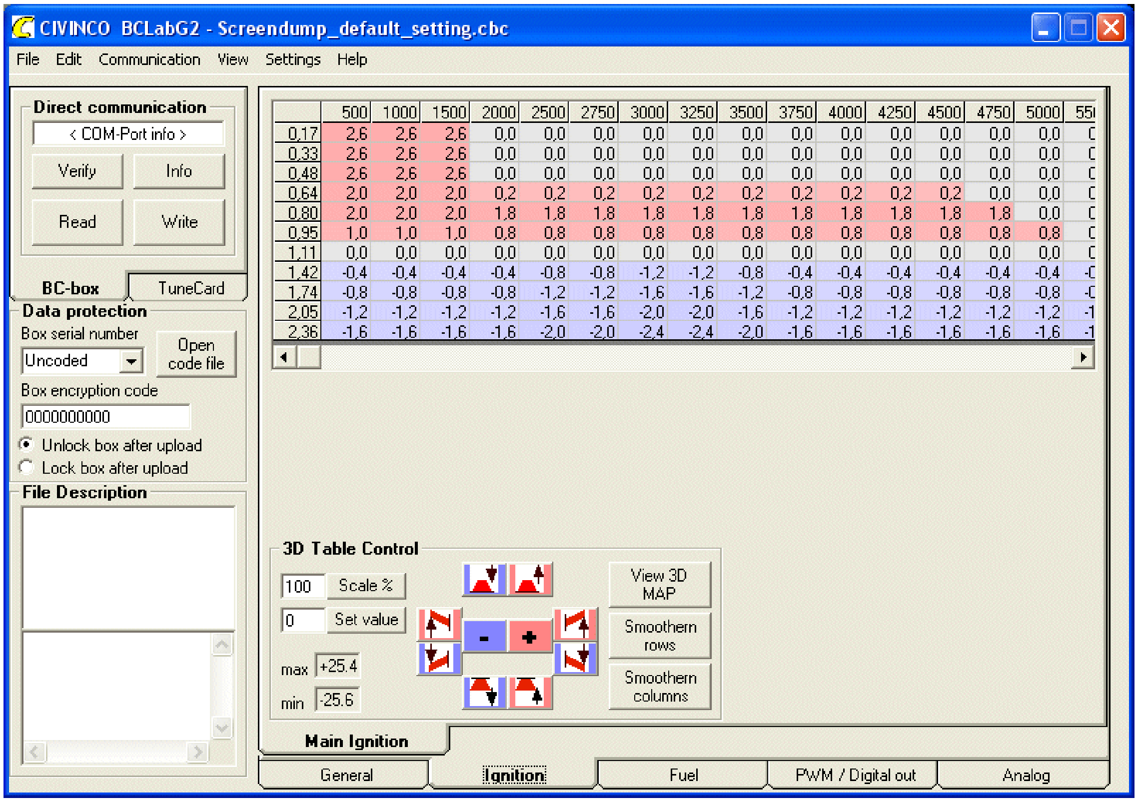
	0	500	1000	1500
0,13	0,0	0,0	0,0	10,0
0,21	0,0	0,0	0,0	10,0
0,29	0,0	0,0	0,0	10,0
0,36	0,0	0,0	0,0	10,0
0,44	0,0	0,0	0,0	10,0
0,52	0,0	0,0	0,0	10,0
0,60	0,0	0,0	0,0	10,0

Becomes

	0	500	1000	1500
0,13	0,0	3,3	6,7	10,0
0,21	0,0	3,3	6,7	10,0
0,29	0,0	3,3	6,7	10,0
0,36	0,0	3,3	6,7	10,0
0,44	0,0	3,3	6,7	10,0
0,52	0,0	3,3	6,7	10,0
0,60	0,0	3,3	6,7	10,0



Ignition



RPM and Load Resolution (number of cells)

You can adjust how many cells and what values the different axles should be. These settings are done in – Settings – Ignition maps

The value shown in the left column depends on what kind of sensor you choose in “Used Analog Sensor”.

Ignition Adjustment

Negative values equals retarded ignition (delayed ignition).

Positive values equals advanced ignition. The iEMS3 can only advance ignition under certain circumstances.

Currently, iEMS3 can advance the ignition in the following cases:

- Dodge Viper, all three generations. This is due to the crank and cam signals are of the digital type (non inductive) and have a special pattern. Inductive sensors will need a special amplifier.

- All engines with distributor and an external ignition amplifier where the ignition pulses are symmetrical with the rpm (2 times/revolution in a 4 cylinder engine)
- Inductive sensors will need a special amplifier.

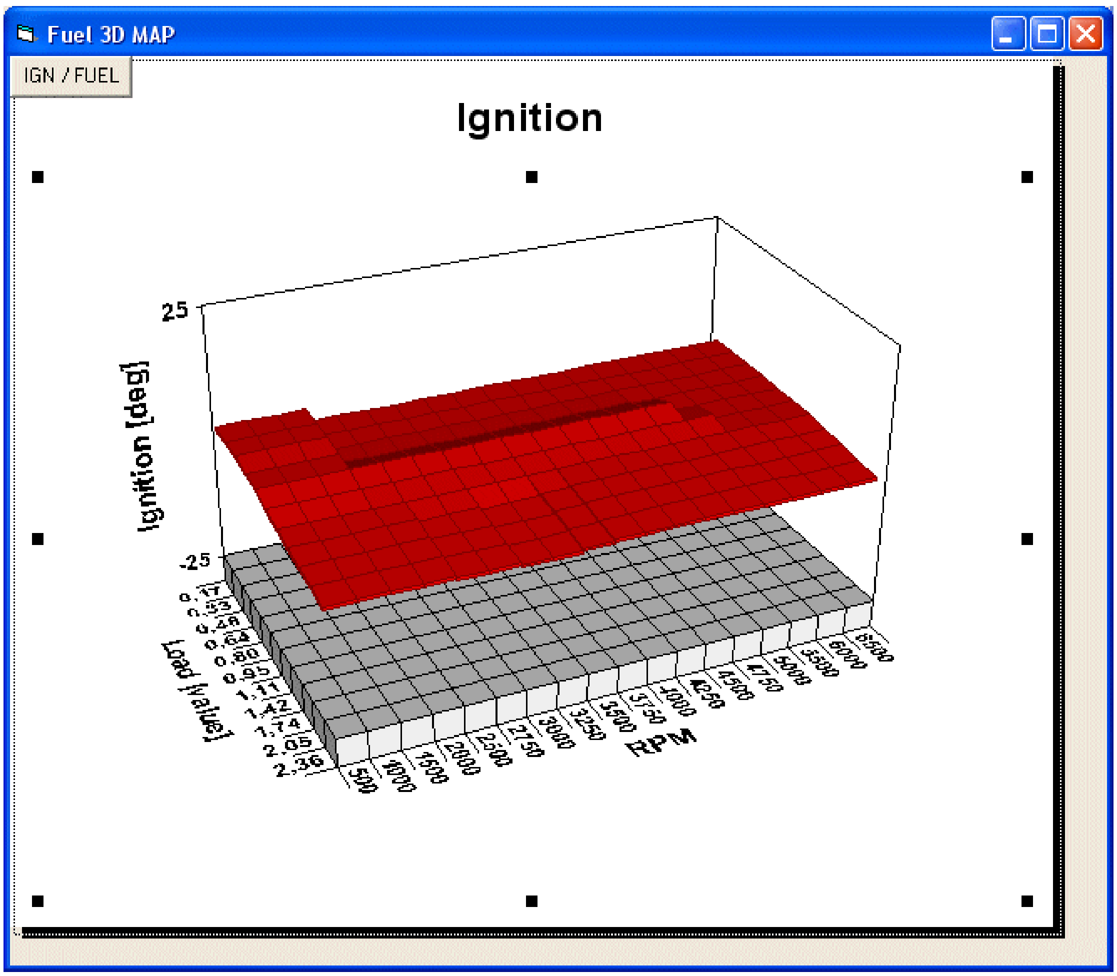
Currently iEMS3 can retard the ignition in the following cases:

- When the ECU ignition signal is low voltage (0-12V or 0-5V and does not drive the ignition coil directly). The BC-box can retard two ignition channels simultaneously (4 channels with the BC1000).
- When the crank and cam signals are of the digital type, max 0-15V (non inductive), with a dutycycle between 40-60% and max 2.5kHz at max rpm (equals 24 teeth at 6000rpm). Shortest pulse length is 100us. Inductive sensors will need a special amplifier.

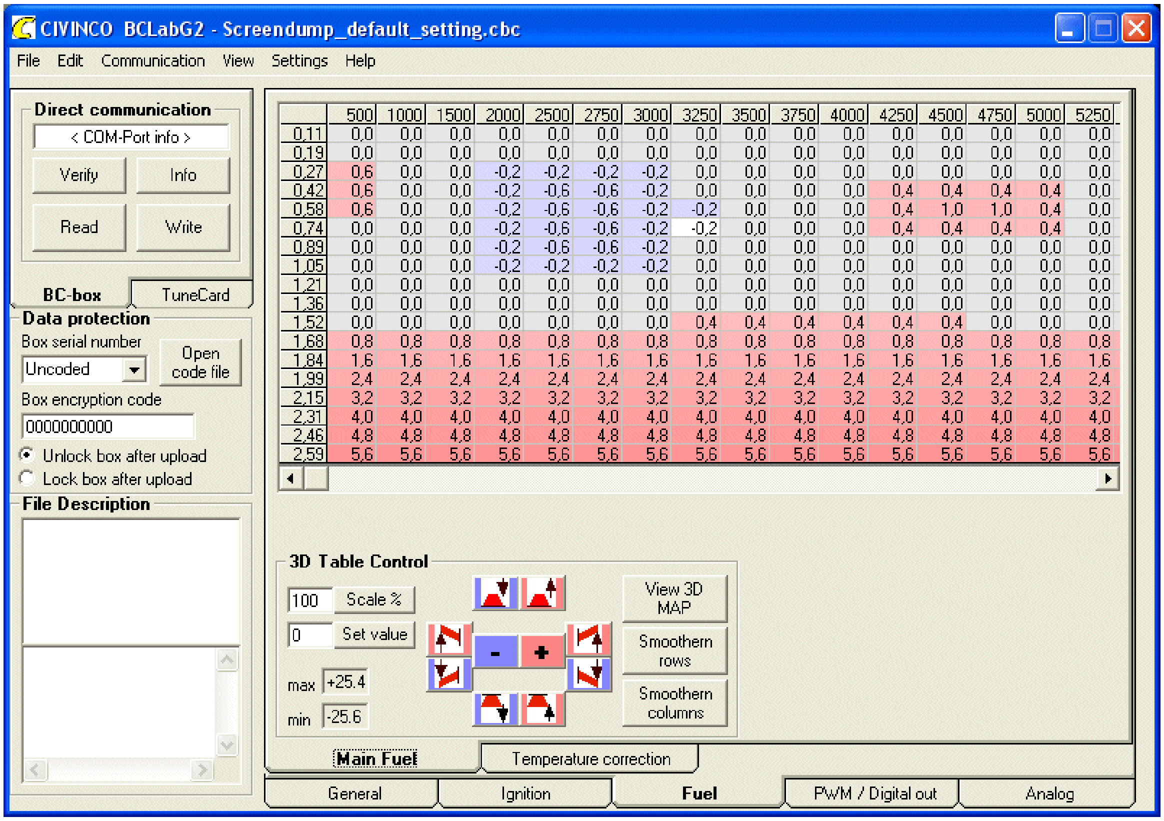
The ignition functions are continuously expanded, call for the latest info.

View 3D Map

Opens a window to view a 3D graph of ignition timing.



Fuel - For a better understanding of the tuning principles see the chapter on Fuel enrichment



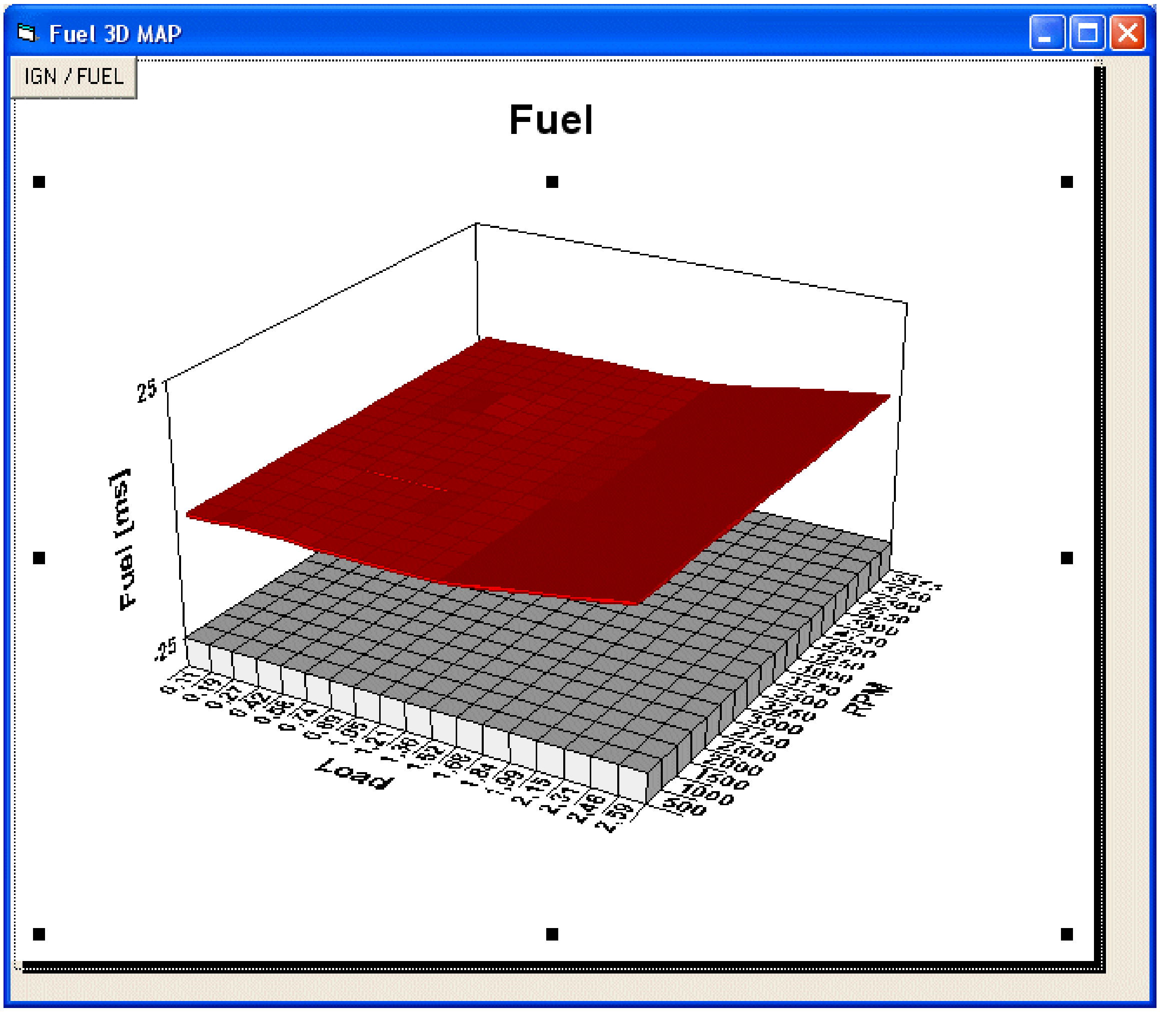
You set how long the base fuel pulse is extended or shortened (in milliseconds) depending on the input signal and the rpm.

RPM and Load Resolution (Number of Cells)

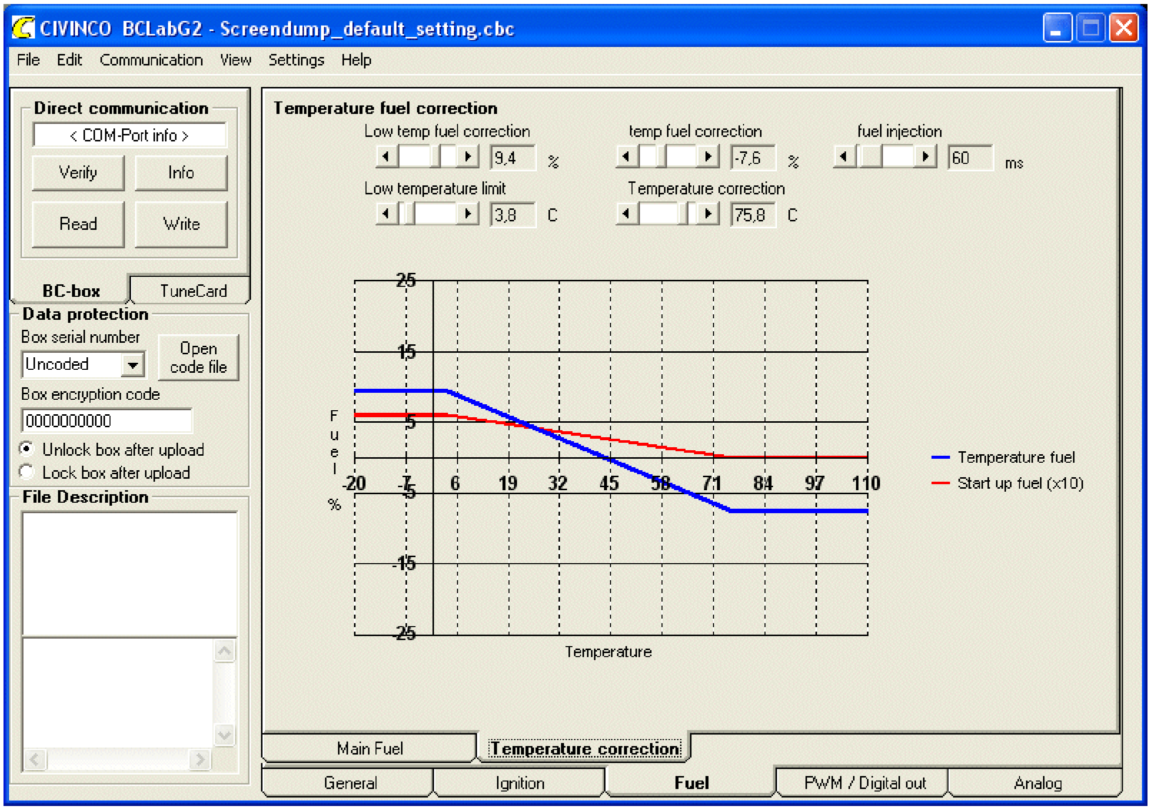
You can adjust how many cells and what values the different axis should be. These settings are done in – Settings – Fuel maps

View 3D Map

Opens a window to view a 3D graph of fuel settings.



IAT compensation



Fuel Temperature Correction

In some cases there's a need to adjust fuel depending on the intake air temperature. With this function you set how much longer /shorter the fuel pulse should be when the engine temperature is low (low temperature limit) or high (High temperature limit). The iEMS3 needs to be connected to an IAT sensor.

Fuel Injection, Start Up Fuel

In some cases you have a need to give lots of extra fuel during start-up when it's cold outside, mostly if your engine runs on ethanol, E85. With this function you can set how long the fuel pulse should be while cranking and the engine is cold (low temperature limit). This fuel pulse gets shorter and shorter depending on how warm the engine is at start-up. If the engine has reached "High temperature limit" there will be no start-up fuel.

The iEMS3 needs to be connected to a water coolant temperature sensor.

PWM / Digital out

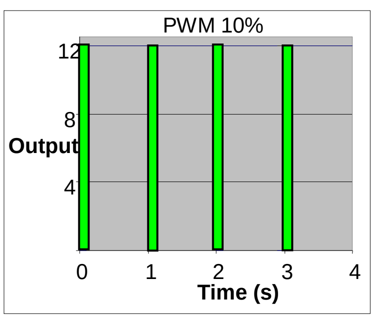
For a better understanding of the principles of tuning refer to the chapter on Boost control.

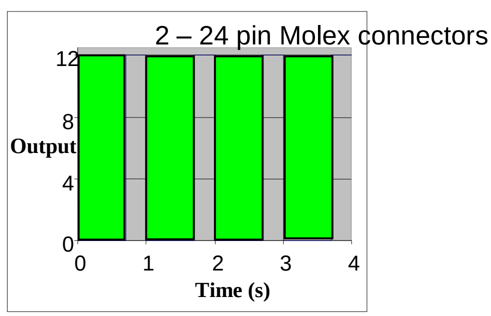
PWM signals

PWM is short for Pulse Width Modulation. This method can be considered equivalent to an analog output voltage and is used for controlling devices (valves, motors etc.) that require somewhat higher power. In real life the signal is actually a switched on/off type 12V signal. The switching occurs very quickly and is thus "smoothed out". If the signal is on and off the same amount of time then the result will be equivalent of a 6V output. The PWM output is specified in % where the equal on - equal off means 50%.

The iEMS3 output will ground the output when active. This means that the controlled device must be 12V positive supplied by other means. A value of 100% means that the device is grounded all the time (active all the time) and 0% means no grounding (non active). The iEMS3 PWM output has a frequency of 38.6 Hz.

In the examples below, the pulse is set for 10% in the first graph and 75% in the second graph. The green bars indicate the relative amount of time that the output is grounded (turned on).



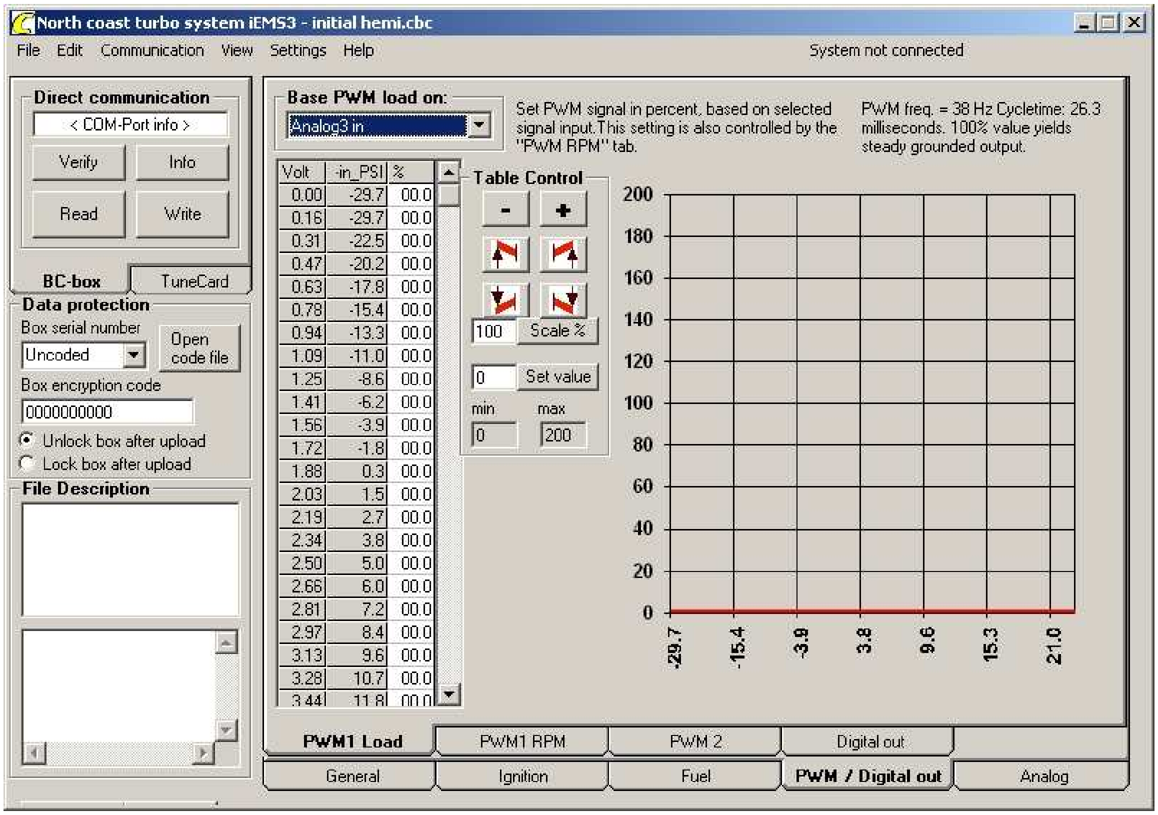


The iEMS3 can use the PWM output to control:

- Boost valve
- VTEC (variable camshaft)
- Nitrous
- Water injection
- Gearshift indication

Normally the PWM uses pin 11 for boost control.

PWM1 Load



Base PWM Load On

Determines which analog input to base the calculation of PWM output. The table values (0-100%) determines the PWM output duty cycle value in percentage as a function of the selected analog input. The PWM output is also controlled by the "PWM RPM" table. The "PWM Load" value is multiplied with the "PWM RPM" value to form the final PWM output value.

Examples:
50% x 50% = 25%
50% x 150% = 75%

Boost pressure is normally controlled by throttle position so that the pressure is low when you push gently on the accelerator. This makes it easier to create a fuel-efficient setting.

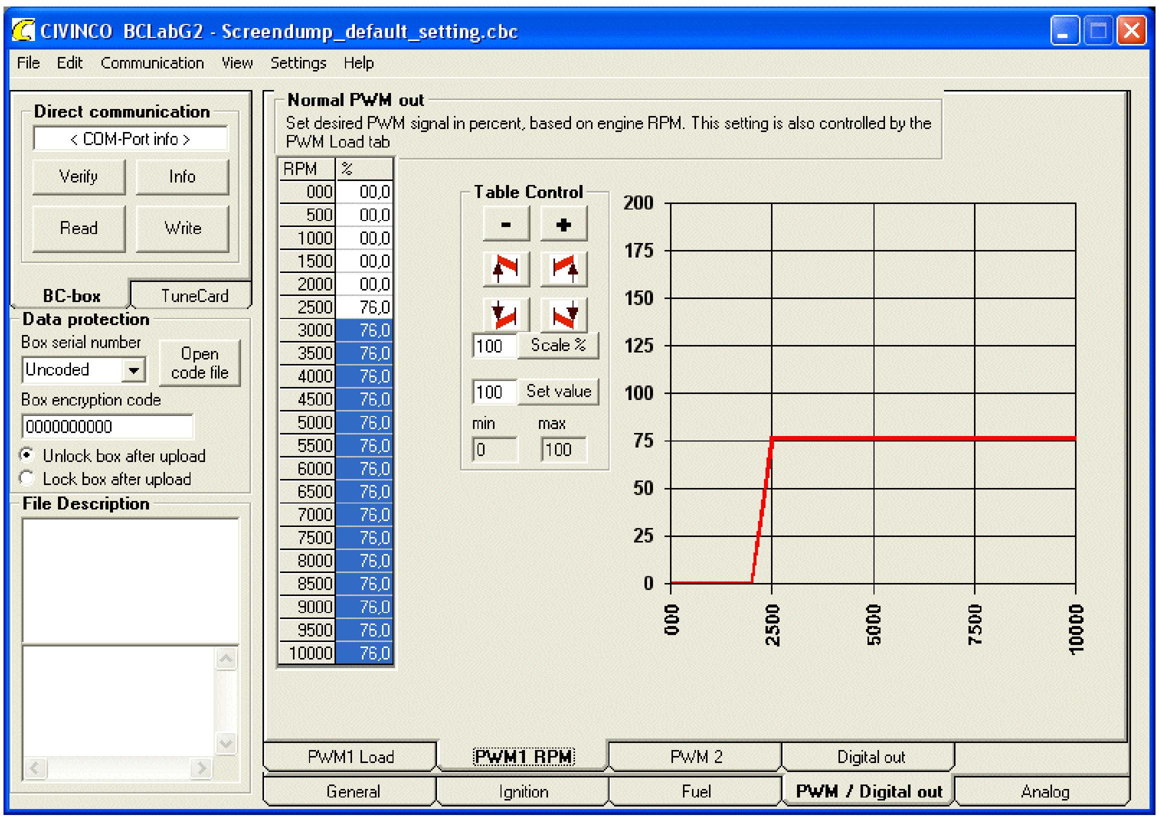
Run PWM as an On/Off Switch

By selecting this option the PWM output is forced active (0V, grounded) as soon as the calculated PWM value is above 50%. The function of the output then resembles an on/off switch. It can be used to turn on/off lamps, relays etc.

Example

Set the entire PWM Load table to 100% (no load influence)
Set the PWM RPM table at 0% up to 6500 rpm and at 100% above this rpm.
This results in PWM_Out is off up to 6500 rpm, and on above 6500rpm. If you connect a lamp between 12V and PWM_Out you now have an rpm-indicator lamp.

PWM1 RPM

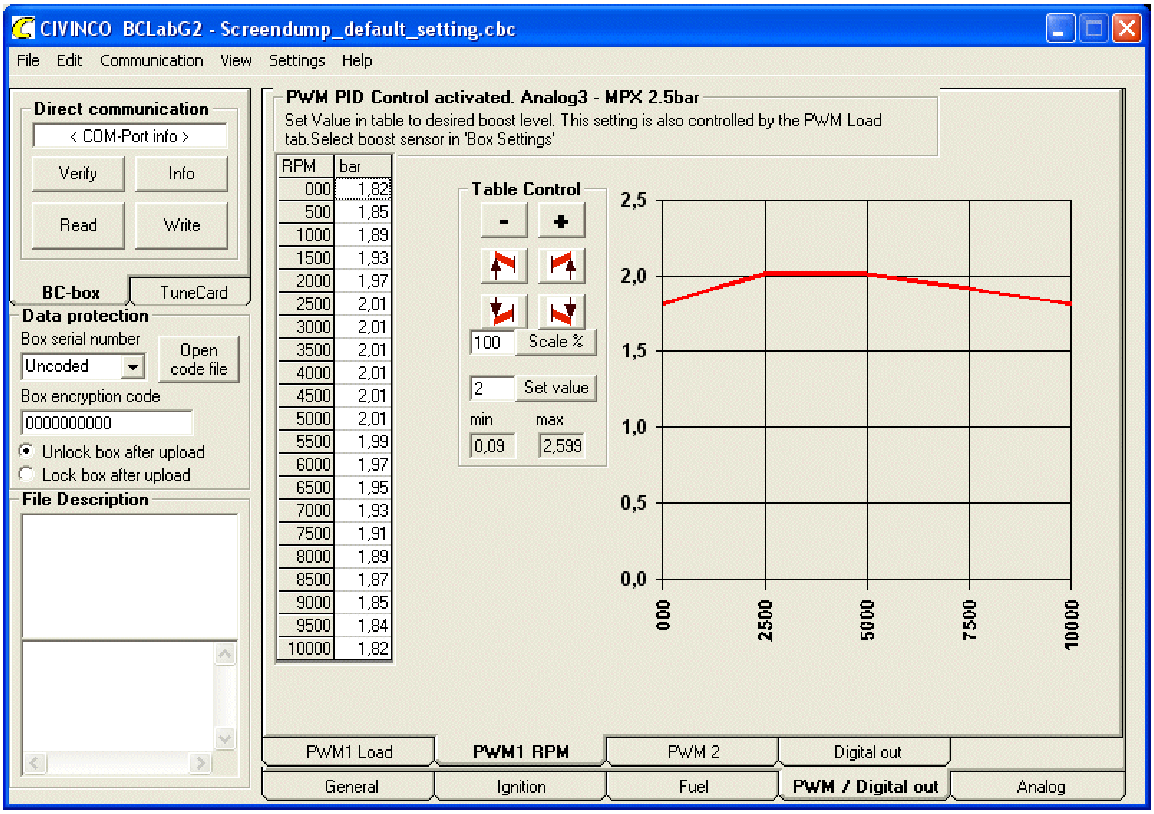


The value 0-100% determines the PWM signals duty cycle in percentage depending on rpm.

If you choose to control a boost control valve, then every PWM-value corresponds to a specific boost. The boost for the different values differs and needs testing to be determined.

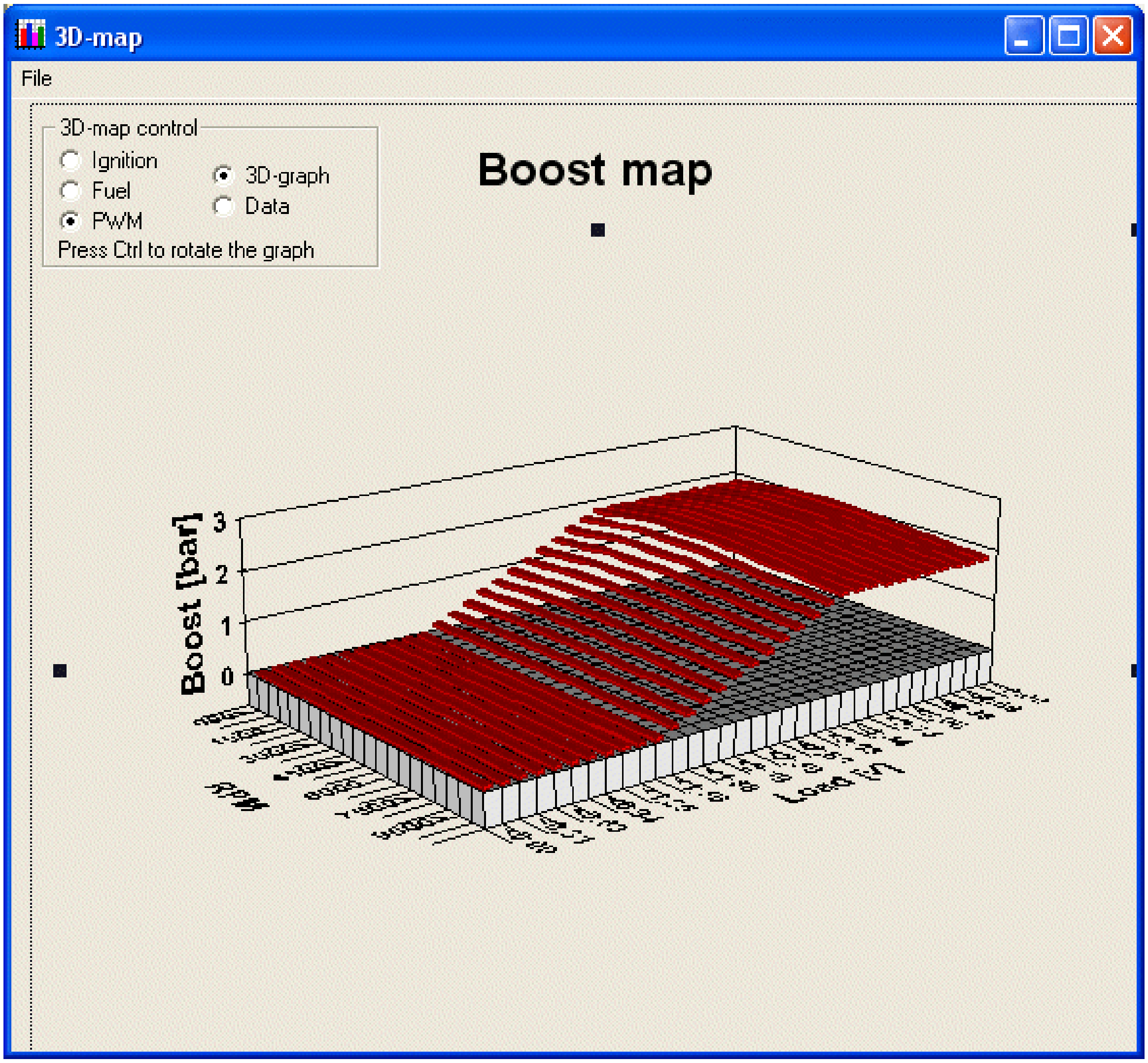
The PWM signal is also controlled from “PWM Load”. See page Run PWM as on/off switch.

PWM RPM with Boost Control

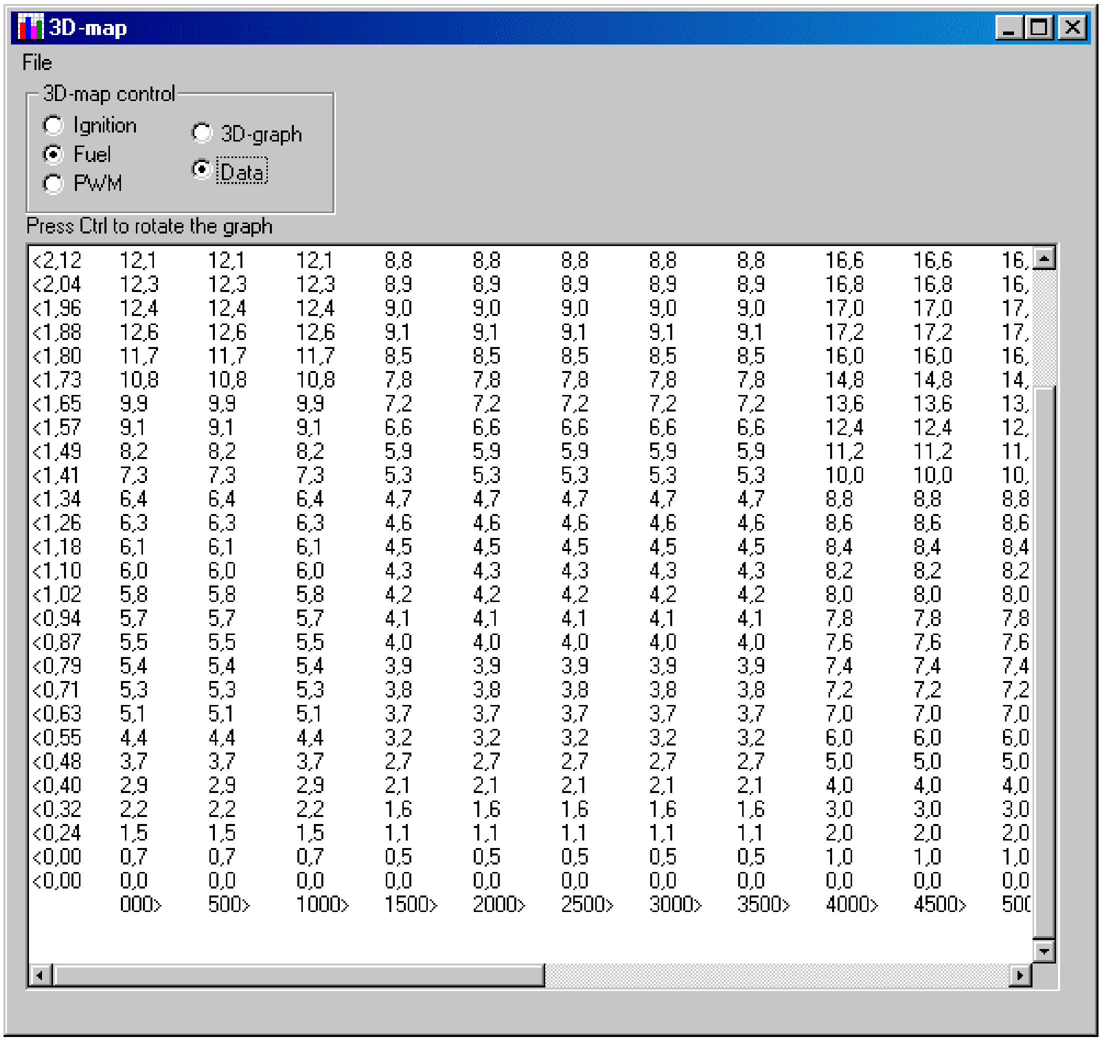


If you chose PID-regulation of boost, you will specify desired boost at every rpm.

3D Map for PWM



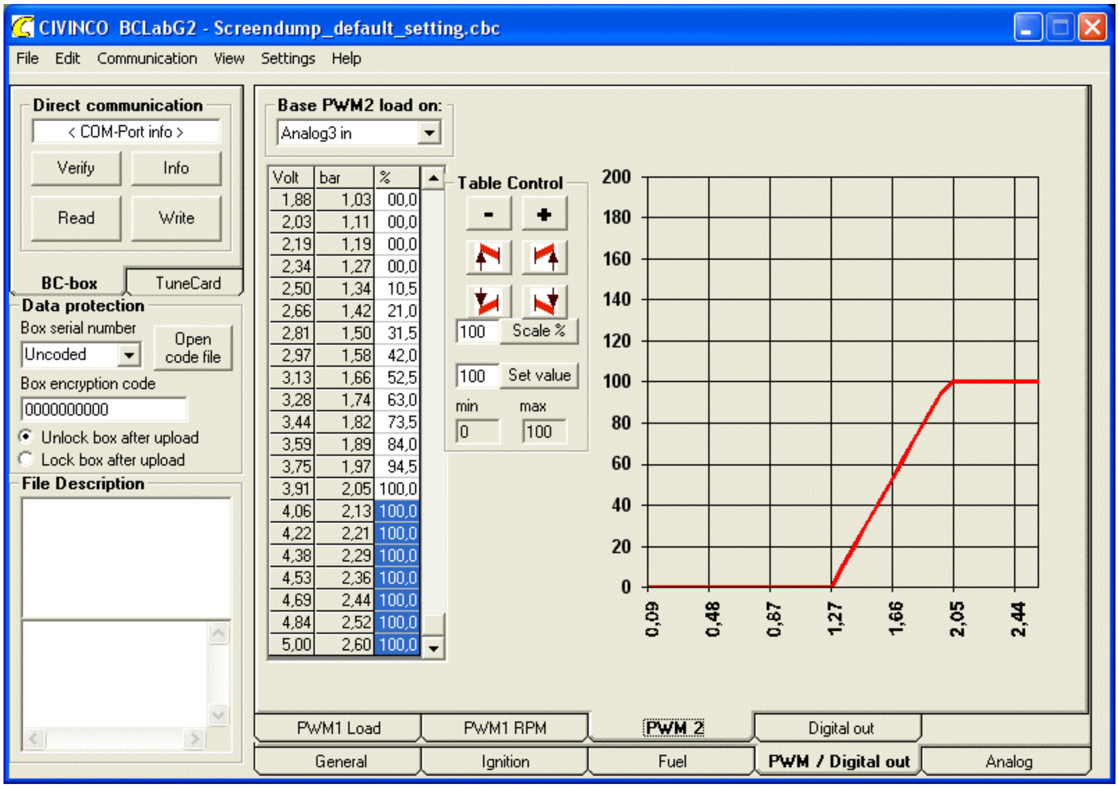
Text Window for 3D Map



<2,12	12,1	12,1	12,1	8,8	8,8	8,8	8,8	8,8	16,6	16,6	16,
<2,04	12,3	12,3	12,3	8,9	8,9	8,9	8,9	8,9	16,8	16,8	16,
<1,96	12,4	12,4	12,4	9,0	9,0	9,0	9,0	9,0	17,0	17,0	17,
<1,88	12,6	12,6	12,6	9,1	9,1	9,1	9,1	9,1	17,2	17,2	17,
<1,80	11,7	11,7	11,7	8,5	8,5	8,5	8,5	8,5	16,0	16,0	16,
<1,73	10,8	10,8	10,8	7,8	7,8	7,8	7,8	7,8	14,8	14,8	14,
<1,65	9,9	9,9	9,9	7,2	7,2	7,2	7,2	7,2	13,6	13,6	13,
<1,57	9,1	9,1	9,1	6,6	6,6	6,6	6,6	6,6	12,4	12,4	12,
<1,49	8,2	8,2	8,2	5,9	5,9	5,9	5,9	5,9	11,2	11,2	11,
<1,41	7,3	7,3	7,3	5,3	5,3	5,3	5,3	5,3	10,0	10,0	10,
<1,34	6,4	6,4	6,4	4,7	4,7	4,7	4,7	4,7	8,8	8,8	8,8
<1,26	6,3	6,3	6,3	4,6	4,6	4,6	4,6	4,6	8,6	8,6	8,6
<1,18	6,1	6,1	6,1	4,5	4,5	4,5	4,5	4,5	8,4	8,4	8,4
<1,10	6,0	6,0	6,0	4,3	4,3	4,3	4,3	4,3	8,2	8,2	8,2
<1,02	5,8	5,8	5,8	4,2	4,2	4,2	4,2	4,2	8,0	8,0	8,0
<0,94	5,7	5,7	5,7	4,1	4,1	4,1	4,1	4,1	7,8	7,8	7,8
<0,87	5,5	5,5	5,5	4,0	4,0	4,0	4,0	4,0	7,6	7,6	7,6
<0,79	5,4	5,4	5,4	3,9	3,9	3,9	3,9	3,9	7,4	7,4	7,4
<0,71	5,3	5,3	5,3	3,8	3,8	3,8	3,8	3,8	7,2	7,2	7,2
<0,63	5,1	5,1	5,1	3,7	3,7	3,7	3,7	3,7	7,0	7,0	7,0
<0,55	4,4	4,4	4,4	3,2	3,2	3,2	3,2	3,2	6,0	6,0	6,0
<0,48	3,7	3,7	3,7	2,7	2,7	2,7	2,7	2,7	5,0	5,0	5,0
<0,40	2,9	2,9	2,9	2,1	2,1	2,1	2,1	2,1	4,0	4,0	4,0
<0,32	2,2	2,2	2,2	1,6	1,6	1,6	1,6	1,6	3,0	3,0	3,0
<0,24	1,5	1,5	1,5	1,1	1,1	1,1	1,1	1,1	2,0	2,0	2,0
<0,00	0,7	0,7	0,7	0,5	0,5	0,5	0,5	0,5	1,0	1,0	1,0
<0,00	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	000>	500>	1000>	1500>	2000>	2500>	3000>	3500>	4000>	4500>	50

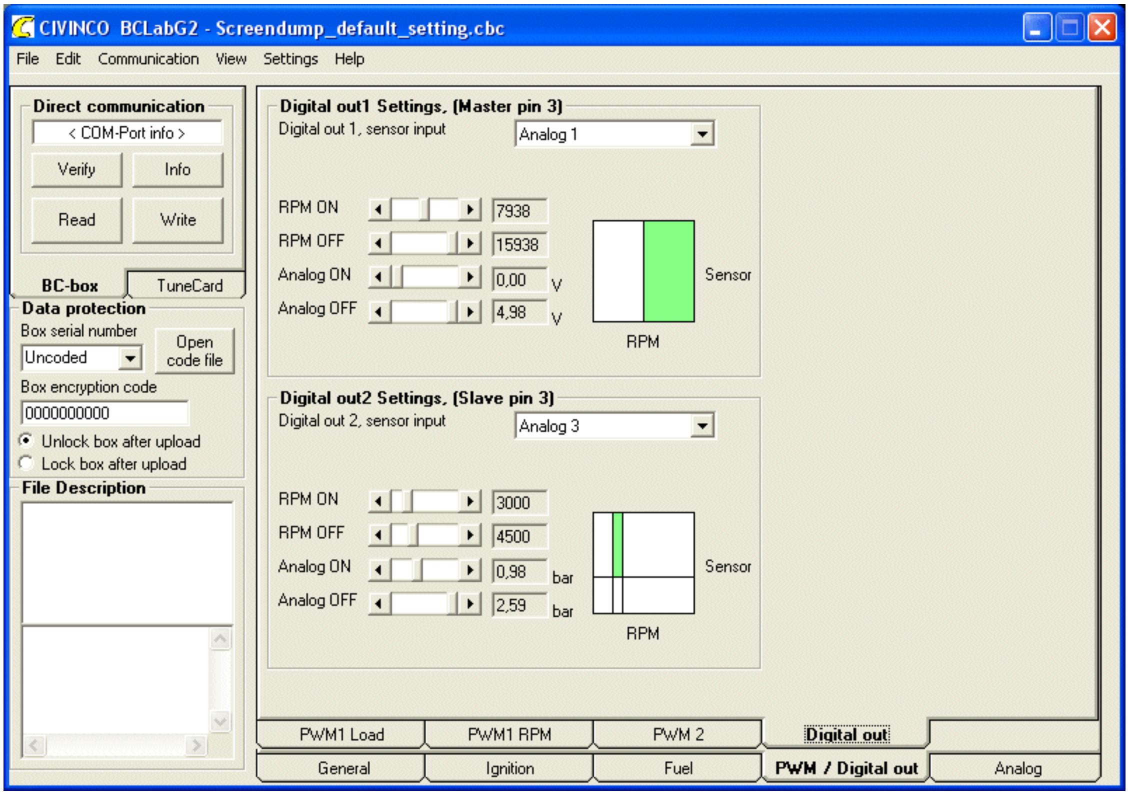
While tuning PWM1 in BCLab you want to look at both rpm and load. You can also view the complete 3D Map for boost pressure. The data is also shown as values in a text window.

PWM2



The iEMS3 IS8G3 also has a PWM2 in the slave connector pin no 5 which can be separately tuned depending on load or rpm.

Digital output 1&2



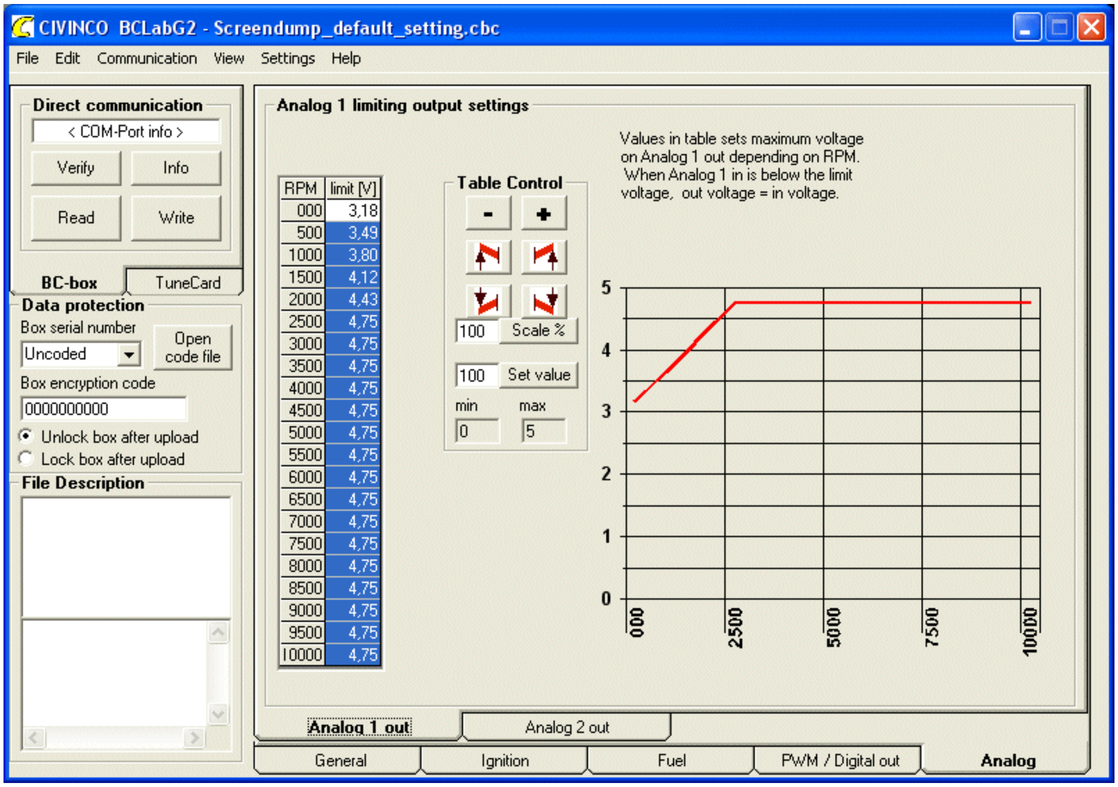
There is one digital output in the master and one in the slave which can be turned on and off depending rpm and an optional analog input. The output is grounded when it's turned on. This means that you connect +12V separately from the battery or ignition key to whatever you would like to control (relay, light etc).

RPM On At what rpm the output should be turned on.
RPM Off At what rpm the output should be turned off again.
Analog On At what analog signal the output should be turned on.
Analog Off At what analog signal the output should be turned of again.
The green area in the box next to each control shows when the output is turned on.

Page - Analog Out

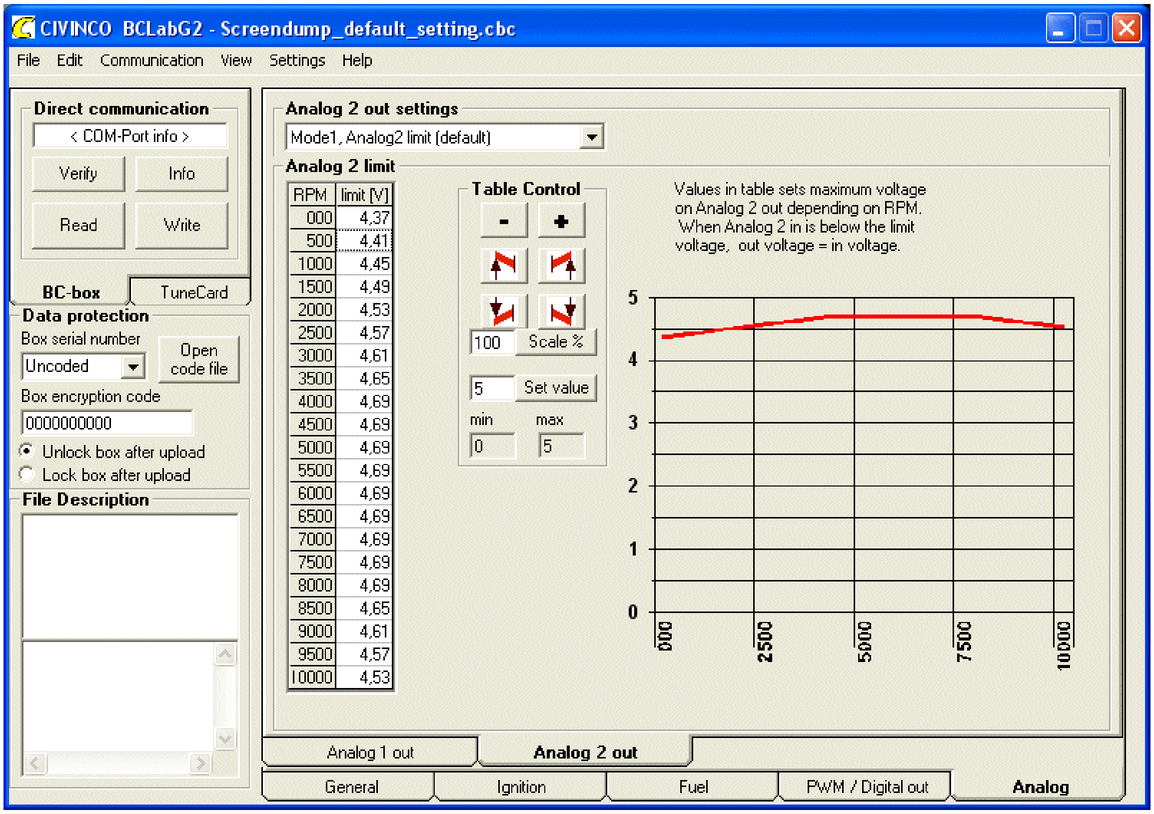
For a better understanding of the tuning principles see the chapter on Signal limiting.

Analog 1 out



The table values (0-5V) determine the maximum analog1 output signal voltage depending on rpm. Below this maximum value the output is the same as the input voltage.

Analog 2 out



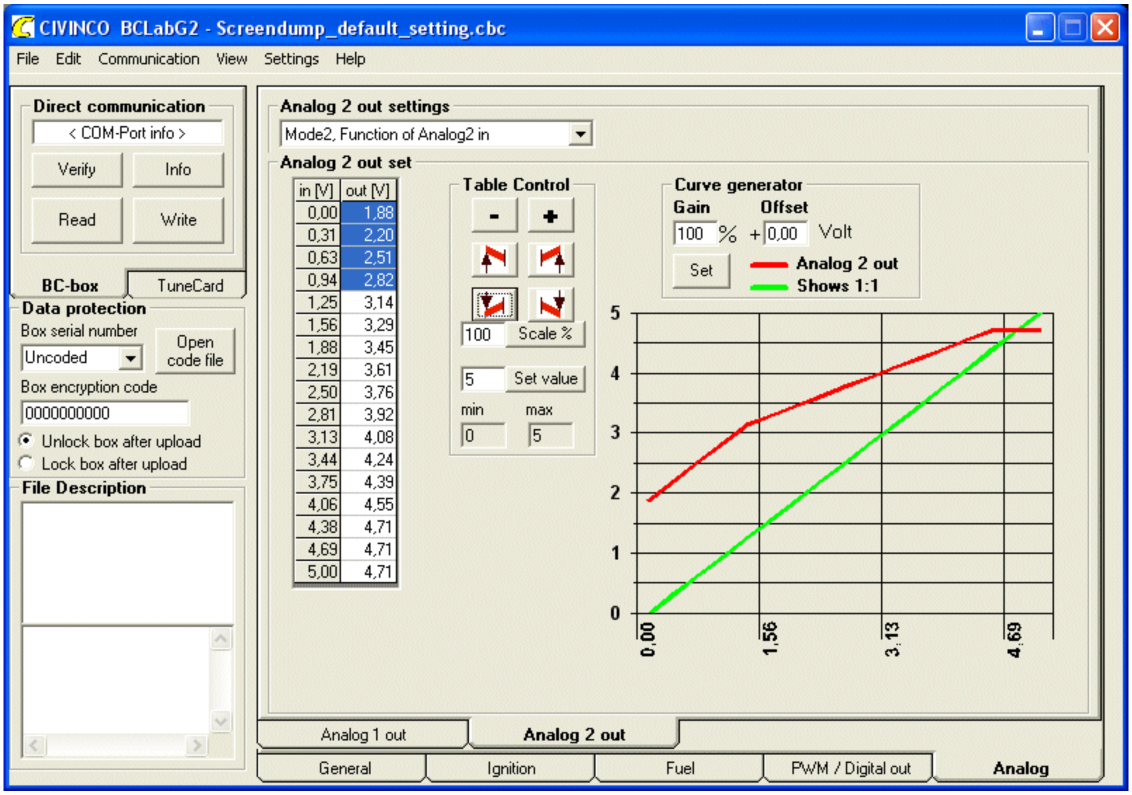
Analog 2 Out Settings

The analog 2 output can be run in 4 modes.

Mode1, Analog 2 limit

Sensor limiting in the same manner as Analog 1.

Mode 2, Function of Analog 2 input



Analog 2 output is calculated as a function of Analog 2 input. The relevant output values are specified in this table.

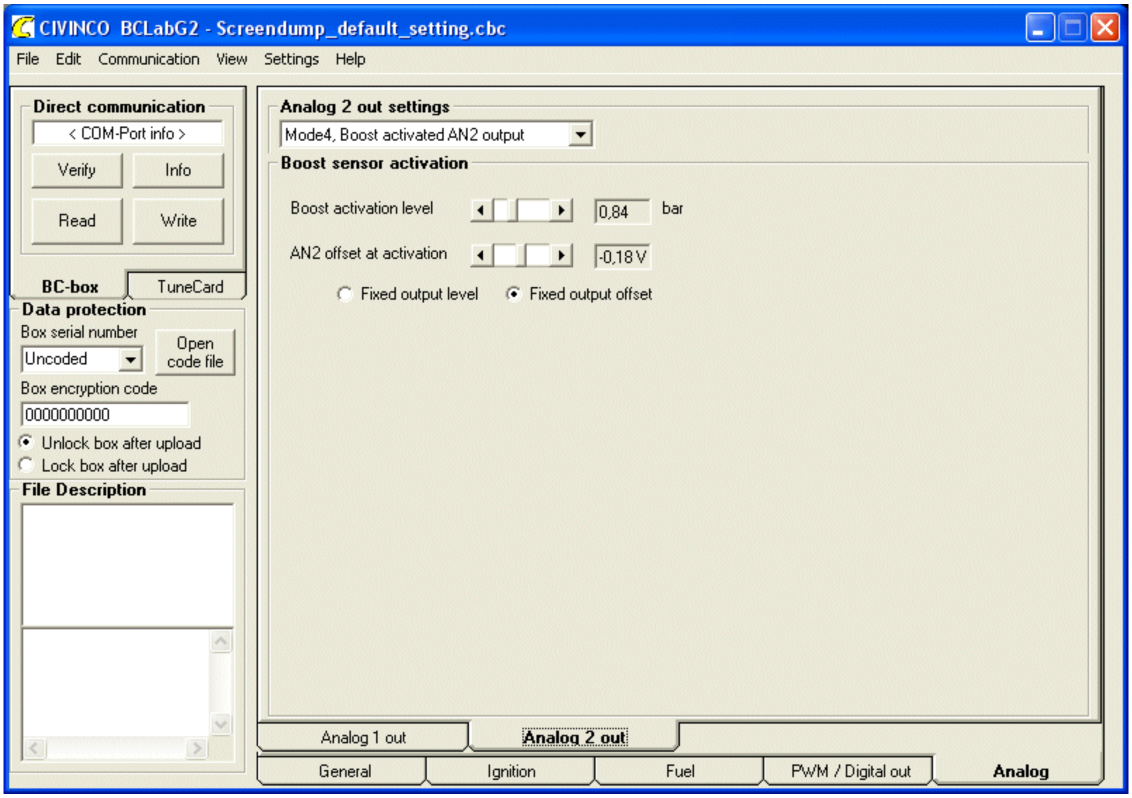
The values in the table can quickly be entered using the Gain and Offset function. The values in the table will be automatically calculated as:

Table value=Offset+[Input]*Gain

Mode 3, Analog 2 limit trim

Same function as Mode 1, but with the addition of "limit trim". This function varies the limited signal to the ECU in a special fashion. This is necessary in some engines as the ECU will detect a fault condition if it tries to regulate the boost but nothing happens (due to sensor limiting). In this mode the iEMS3 will detect the ECU trying to regulate boost and adjust the limited signal enough to make the ECU think it is actually regulating boost. This only works when connecting the boost pressure feedback signal to the IGB_IN pin.

Mode 4, Boost activated AN2 output



This can control Analog 2 out when you exceed a certain boost pressure (or any other analog input signal).

There are two options:

- Analog 2 out is set to a certain value.

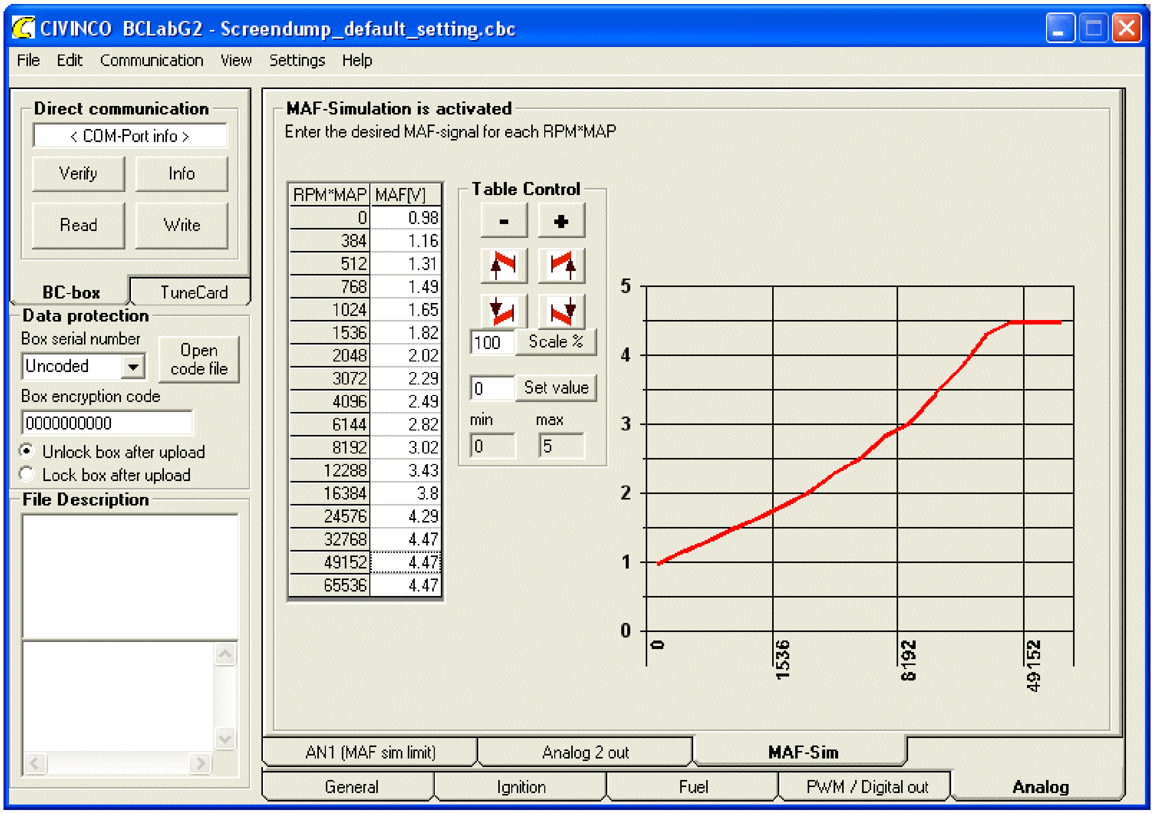
  This is often used to tweak the AFR signal by connecting a resistance between Analog 2 out and the AFR signal.

- Analog 2 should be the value 1, add or subtract a certain voltage to the Analog 2 input.

  This function is used when you want to offset the AFR signal with a specific voltage at a specific boost pressure.

Mass Airflow Simulation

When using mass airflow simulation the Analog1 table is used to specify the Mass airflow simulation. For every individual engine you must specify/tune which output signal to be generated based on rpm and manifold pressure. The iEMS3 automatically calculates the product of rpm*(A/D-conversion of MAP sensor)*32. Depending on this product the iEMS3 reads the table and finds the correct voltage to be used as Mass airflow simulation signal.

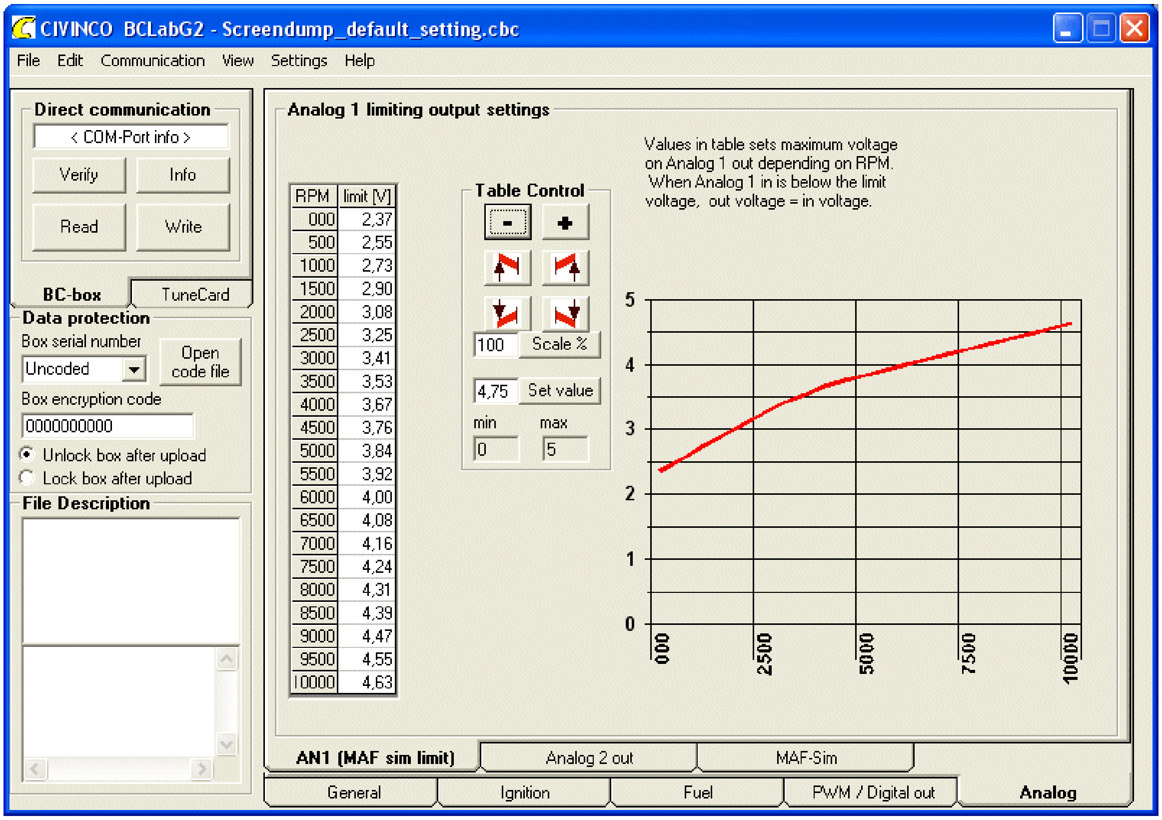


Example:

Rpm: 3500 (3.5krpm)
MAP: 2.44 volt at MAP sensor
Product: 3.5*2.45*1632=13994
Mass airflow sim signal: 3.43V (Closest table value is 12288)

Mass Airflow Simulation Limit

In some cases you have to limit the simulated signal on a specific rpm and hide it from the ECU, even though the calculated mass airflow is higher. This limit is set in the table below.



Main menu – File

Open - Opens a TuneCard tuning file which is previously saved on disk. The files are denoted .cbc files.

Save - Saves the current BCLab settings to the presently open TuneCard file

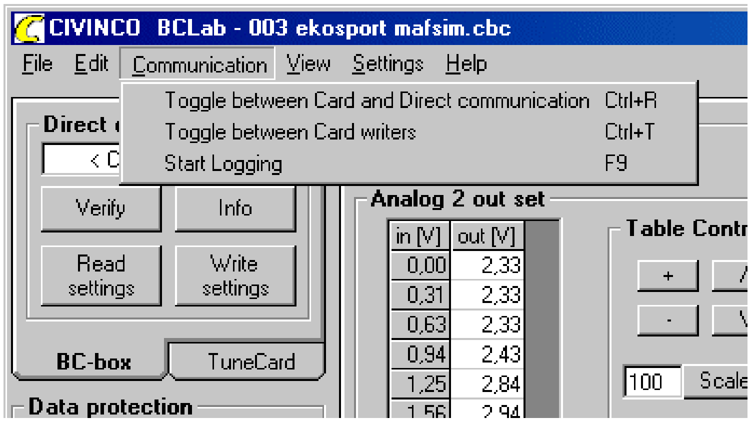
Save As - Saves the current BCLab settings to a TuneCard file with a new name

Exit - Exits BCLab

Main menu – Edit

Undo - Undo the last pressed button, **Redo** - Redoes the latest "Undo"

Main menu – Communication



For more details, see page General/Chipdrive status

Toggle between Card and Direct communication (Ctrl+R)

Toggles between communication with the BC-box and the TuneCard . Same as clicking on page ”iEMS3” or ”TuneCard”.

Toggle between Card writers (Ctrl+T)

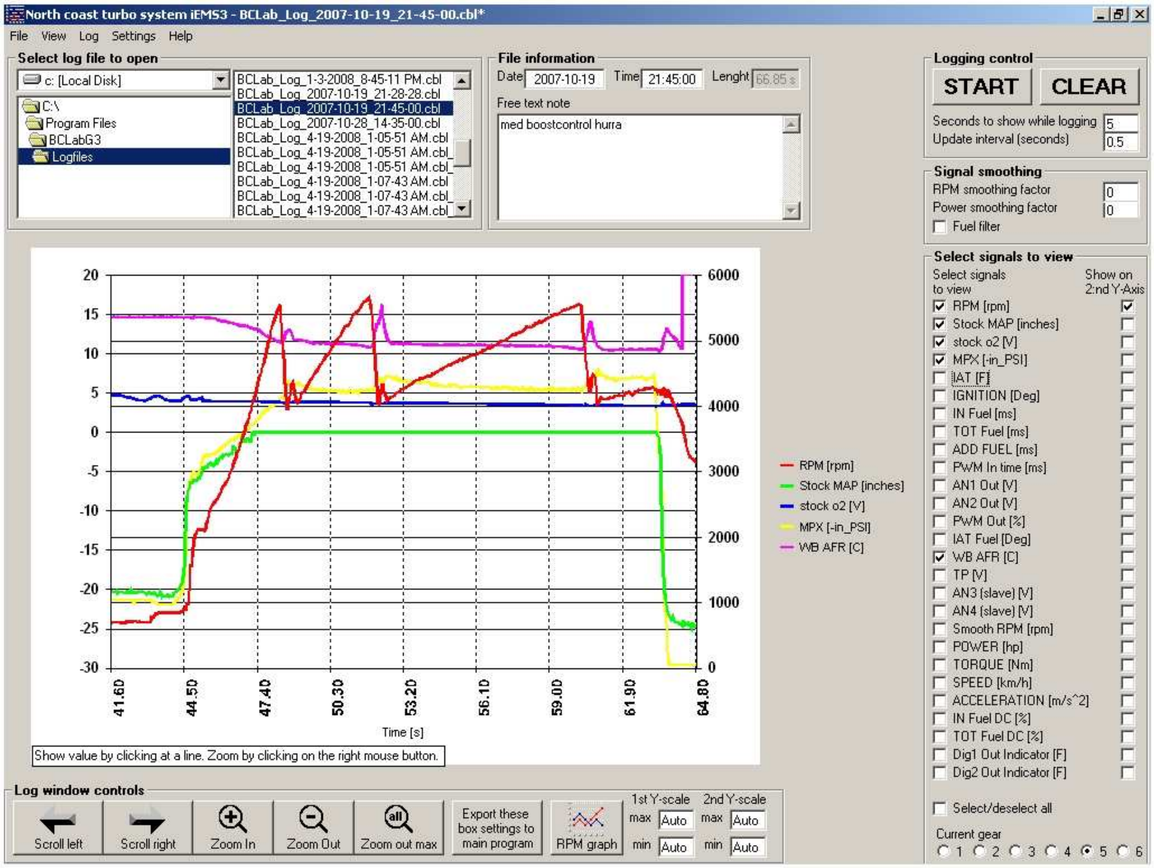
Toggles between different card readers. Supported readers are Chipdrive, Todos and the use of the iEMS3 as a card reader.

Start Logging

Starts logging without opening the log window.

Main menu – View

Log window



The BCLab software can log all signals connected to the iEMS3 in realtime with 20Hz sampling frequency. BCLab can also use these signals to calculate secondary values such as:

- Engine power
- Engine torque
- Speed
- Acceleration
- Duty Cycle of stock fuel pulse and BC-box fuel pulse (used to detect 100% fuel situation)

BCLab shows all data in the logging graph. You may also save the data to disk for later viewing. Some of the possible settings: Name all signals, many typical sensors to choose from, metric or US units, gearing at all gears, etc.

Select Log File to Open

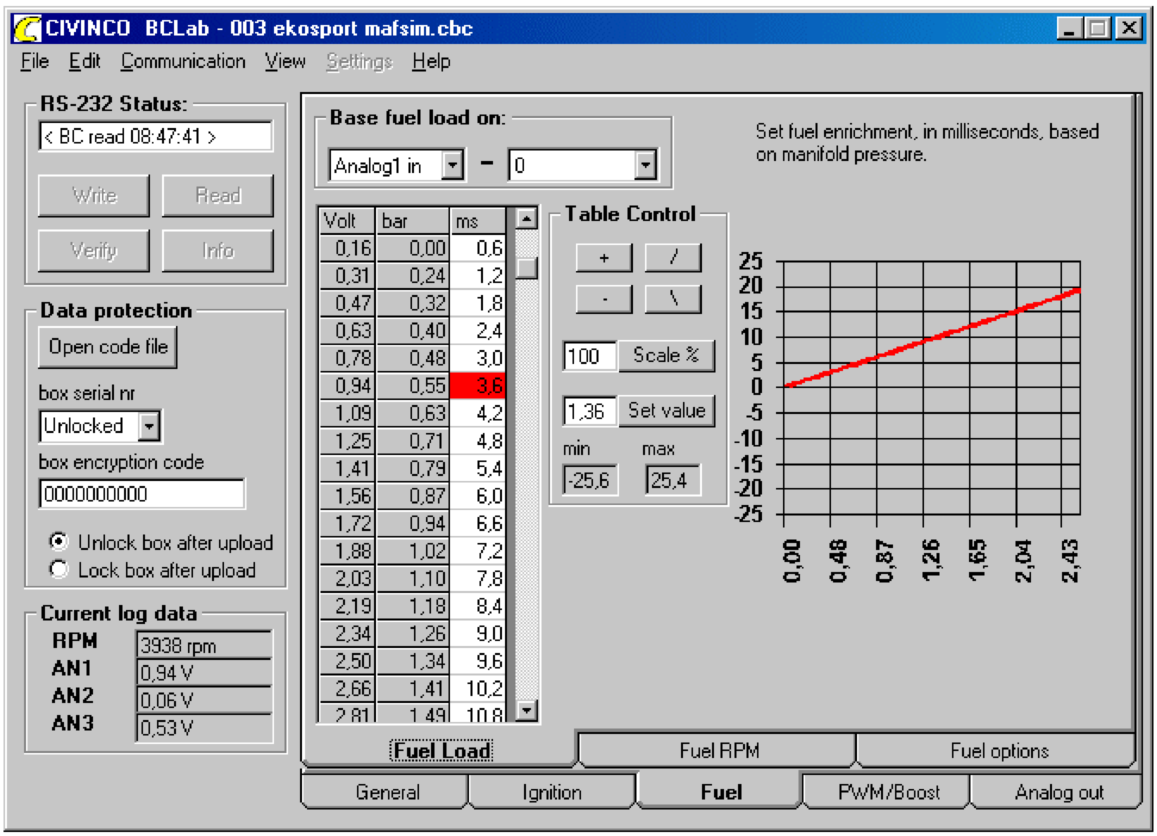
Double click on a saved log file to open it. Same function in File/Open. If single clicking on the file you will see a preview on the comments on this log file, date and size. This will not open the file.

File Information

At all logging the time and date will automatically be added to the file. You may also write your own comments about this log run in the "Free text note".

Logging

Starts, stops and erases the logging. Make sure your iEMS3 is connected via USB.



The log data is also shown in a real-time graph. A red marker shows the currently active tuning cell in the load/rpm tables. This marker will enable you to quickly see where in the table the iEMS3 is working. This will speed up the tuning process.

Seconds to show while logging

Specifies how many seconds of logging data are to be shown on the screen. If you have a slow computer you can decrease this value for proper function. Normally we set this to 5-10 seconds.

Update interval

This specifies how often the live graph is updated while logging. If you have a slow computer you may need to increase this value. Normally we set this value to 0.1-1 second.

Chart Scale Options

Sets the min and max displayed values on the Y-axis in the graph. If selected to Auto the program will adjust this as necessary.

Select Signals to View

You will select the desired signals to view in the graph.
You can also choose if the signal is to be displayed on the 1st or 2nd Y-axis. This is practical if displaying two signals which differ a lot in magnitude, which might otherwise make them difficult to see in the graph. Normally we set the rpm to be displayed on the 2nd Y-axis while all other signals are displayed on the 1st Y-axis. This is because the rpm value is often much larger than the rest of the signals.

Chart Controls

Scroll left - Moves the graph to display earlier values (more to the left)

Scroll right - Moves the graph to display later values (more to the right)

Zoom in - Zooms in on the graph. Doubles the magnification

Zoom out - Zooms out on the graph. Haves the magnification

Zoom all - Zooms out on the graph so the whole graph is displayed

Redraw - Redraws the graph

Specific values in the graph

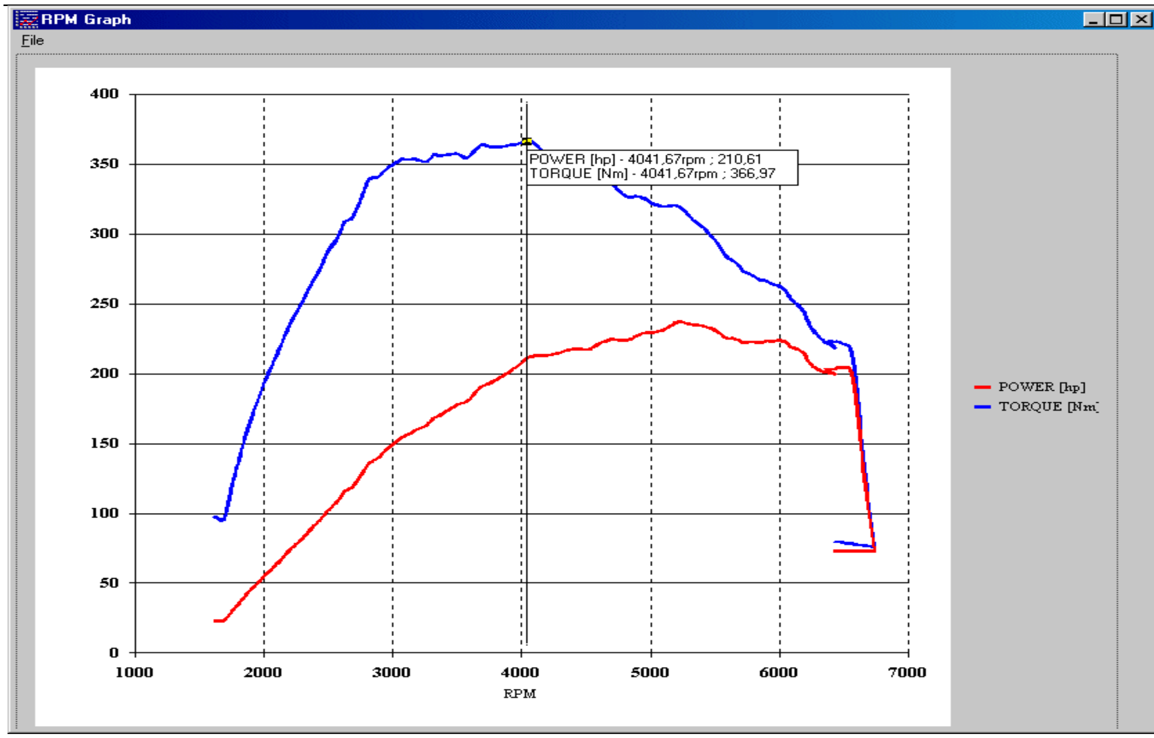
To see the value of a specific point in the graph you can click on it. To move the cursor right or left you can use “Page up” or “Page down”.

Export These Settings to iEMS3

If you have opened an old log file which has the tuning data saved in the log file, you can transfer these tuning data to BCLab by clicking this button. This means that you can see the tuning used by the iEMS3 when the logging was performed. This is useful if you find an old log file where the engine ran very well and want to use these tuning data again.

Refer to chapter BC Log settings for more info on logging setup.

Show RPM graph



RPM graph shows the same values as the normal log window but the rpm is displayed on the x-axis. This function is good when you want to analyze how different logged values vary depending on rpm. Normally you use this for engine power, engine torque, Oxygen sensor etc.

Main Menu File

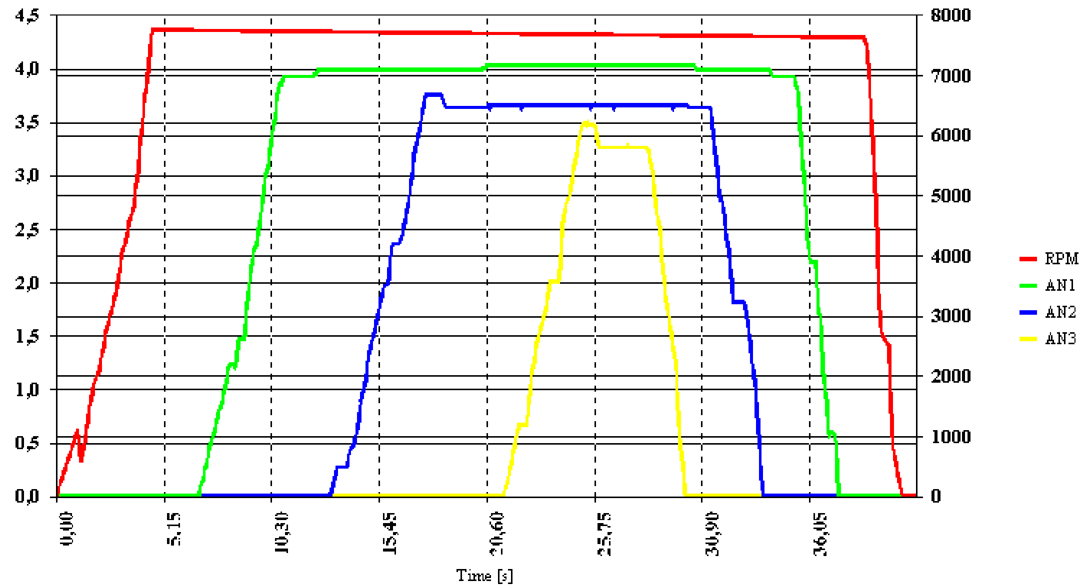
Open - Opens a log file containing saved setups. These files are denoted .cbl files.

Save - Saves the current log file

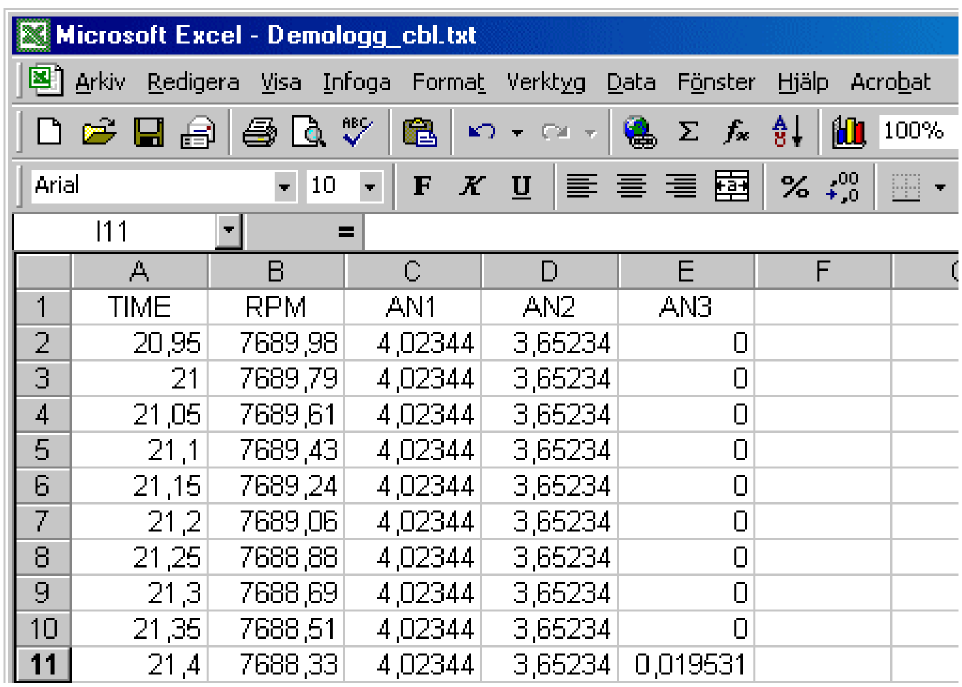
Save As - Saves the current log file with a new name

Export log data

Saves the current log data shown in the log window, either as a picture or as a text file which can be opened in Excel.



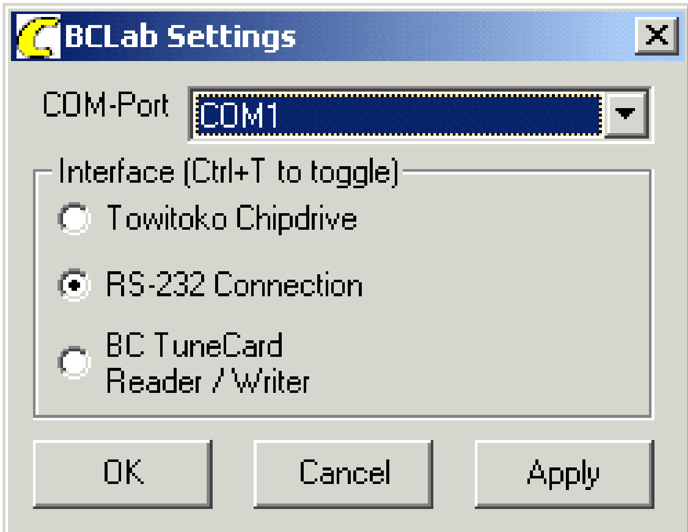
Log window exported as a picture



	A	B	C	D	E	F
1	TIME	RPM	AN1	AN2	AN3	
2	20,95	7689,98	4,02344	3,65234	0	
3	21	7689,79	4,02344	3,65234	0	
4	21,05	7689,61	4,02344	3,65234	0	
5	21,1	7689,43	4,02344	3,65234	0	
6	21,15	7689,24	4,02344	3,65234	0	
7	21,2	7689,06	4,02344	3,65234	0	
8	21,25	7688,88	4,02344	3,65234	0	
9	21,3	7688,69	4,02344	3,65234	0	
10	21,35	7688,51	4,02344	3,65234	0	
11	21,4	7688,33	4,02344	3,65234	0,019531	

Main menu – Settings

BCLab settings



COM Port

Use this to select the PC comport used to connect to the BC-box

Interface

Use this to select one of three ways to communicate with your BC-box and TuneCards.
Also refer to page General/Chipdrive status

Do not connect your Windows PC to the iEMS3 until AFTER the PC has finished booting. If it is connected while it is booting up, the Windows "Plug-N-Play" may see the unit as a USB device and try to install it as such. If you have this happen, disconnect from the iEMS3 and reboot to clear the problem.

At this point, you should have set up all the functions, sensors, and options in the software. If not, this needs to be performed before going any further. Depending on the vehicle model you have, there may be base configuration file available. Check the download page at www.iems3.com for the particular unit that you purchased. Make sure you are running the latest software version available for your unit as well.

All iEMS3 "In Series" units started production with Dataset 109. The software should be iEMS3 version 3.7.44 or later.

Verify setup

Verify that the following areas in the various software tabs are setup for your vehicle. If you missed any, go back and review the section relating to that area of the software.

From the top bar menu, select “Settings” > “Box Settings”

Standard Box Settings Tab

General Dataset 109 or later
Ignition Tables
RPM Indicator

Advanced Settings Tab

BC Digital I/O mode
Ignition (Master and Slave if IS8G3)
Enrichment
MAF Simulation
RPM Calculation (Master and Slave if IS8G3)
Sequential fuel or not
Analog input synchronization
Boost Options

Fuel Tab

3D RPM and Map axis set
3 D Fuel options
Base fuel load on
Verify the Load and RPM columns have the desired span

Ignition Tab

3D RPM and Map Table set
Ignition setting
Base ignition load on
Verify the Load and RPM columns have the desired span

Fuel Options Tab

Boost fuel enrichment method
Base fuel calculations
Acceleration fuel enrichment
Rev limit
Force injector to open

PID Boost Control Tab

PWM1 PID Regulator

From the top bar menu, select “PC Settings”

Box as Card Reader/Writer should be the default
Verify PC Operating system
Com port will show when connected to the unit

From the top bar menu, select “Log Settings” then select “Log Settings” again

Log Sensor Settings
Car Settings (if used)

From the top bar menu, select “Sensor Settings”

Used Analog Sensors for Tuning
Sensor Viewer (to create or change sensor definitions)

Ignition Tab

Main ignition - Verify proper map axis

Fuel Tab

Main fuel - Verify proper map axis
Temperature correction - Unless used, under Temperature Fuel Correction, top three rows should be 0%, 0%, and 0 ms

PWM/Digital Out Tab

PWM1 Load – set or verify sensor used for “Base PWM1 Load On”
PWM1 RPM – Verify table axis
PWM2 – set or verify sensor used for “Base PWM2 Load On”
Digital Out 1 settings
Digital Out 2 settings

Analog Tab

Analog 1 Out - set or verify sensor used for “Analog 1 out settings”
Analog 2 Out - set or verify sensor used for “Analog 2 out settings”

Once you have verified the setup, you should save the file as “My Base File” or similar on your PC so you will recognize it as the original start up file.

Fuel tuning in the iEMS3 is very straight forward. All corrections are based on the length of the injector fuel pulse in milliseconds. A normal vehicle pulse width at idle is generally around 1.5 to 2 milliseconds in length. Maximum fuel pulse length is around 20 milliseconds. Beyond that, at high RPMS there is no longer any time to inject fuel. So if you are running near 20 milliseconds of injector pulse width on the top end, you are very close to running out of injector.

If you are running a 50% larger injector, the iEMS3 base value is going to cut the factory ECU fuel pulse length in half. A correct value in the percent larger window sets the basis for everything else across the fuel map. However, since the injector pulse width is normally about 2 ms at idle, and you cut it in half, you are now at the

point of the injector opening time being greater than the fuel pulse. This would mean no fuel at idle. This is compensated by using the fuel offset. Since the max pulse length is 20 ms, a value of .50 ms would equate to approximately 2.5 % of the injectors capability. This has a negligible impact in the upper RPM range, but is crucial for proper idle. The larger the injector ratio, the larger the offset will be. Most settings will fall somewhere between .25 ms and .50 ms.

Turn the ignition to the "ON" position at this time (do not start). Verify iEMS3 front panel lights light up, and the power indicating light is on. You will likely get some type of code on the first key on, ignore at this point. You will need to click on the "Write" button on the software to load the base file into the iEMS3.

Once this is accomplished, turn the key back off, and then back to the "ON" position (do not start). Using your scan tool or other OBDII device, clear any codes in the ECU. After the codes are cleared, turn the key back off and then back to the "ON" position. Verify that you did not receive any additional ECU codes. If so, diagnose prior to the inital start. Generally these are related to a connection problem in the harness. Recheck the associated connections for loose or missed connections or proper "IN" and "OUT" configurations.

NOTE: Some vehicles take a Barometric pressure reading from the MAP sensor in the first few key on milliseconds. Your iEMS3 should be connected to the power feed to the ECU directly. **DO NOT CONNECT THE LOAD BOARD POWER LEAD TO THE ECU POWER!** It can place too much load on the ECU circuit, so wire the Load Board power lead to a separate key on power source.

If you get a code for LOW MAP SENSOR VOLTAGE, this is indicative of the ECU powering up prior to the iEMS3 and not seeing the expected MAP sensor voltage. Usually this is not an every start occurrence and can vary in frequency if this is an issue. Key off, back to key on, clear code, then normal start usually takes care of the issue for the short term.

If this is an issue, a permanent fix can be accomplished by adding a timed relay circuit triggered from the interior light with the time out set to a value of 10 minutes to ensure power even if sitting in the vehicle for an extended period prior to start. This will provide power up to the iEMS3 prior to the ECU start sequence. We have timer boards available if needed.

Once all checks are completed, it is time for the initial start. Make sure you have a scan tool connected so you can see the fuel trim activity. Start the engine and Monitor the ECU operating mode. This will tell you what mode the ECU is operating in and what the fuel trims are. Once warmed up completely it should report CLOSED LOOP mode and you should see the fuel trims come alive.

If the vehicle fails to start, it is likely there is not enough injector offset in the base file to allow the new larger injectors to be open a sufficient time at idle/start up. Increase

the value in .10 larger increments. Normally with a new style 50% larger injector the value will be between .25 and .50 milliseconds of offset.

As you make changes, get into the habit of “SAVE” and then “WRITE” so you keep your PC and iEMS3 box in sync with each other.

Once started, you want to monitor the direction of the short and long-term fuel trims at idle. If you are under compensating for the larger injector size, the ECU should recognize that too much fuel is being injected and start pulling fuel out. This will be reported by **NEGATIVE TRIM** values. Once they stabilize, see what the value is. If it is negative you will need to increase either the percent larger value (large change needed), or the injector offset value (very small change needed). If the trims are positive, then you are overcompensating, and you will need to reduce the percent value or offset value.

Your goal is to find the values that will drive both fuel trims into single digits. It is doubtful you will ever get near zero. Keep in mind, that short term trims react fairly quickly, and long term are very slow to react, so don’t over do it trying to force a change rapidly. As long as it is idling smoothly and the trims are not maxed out (generally about 25% to 32% + or -), let it run for a while to stabilize. Also, you need to learn how to read between the lines as well.

The ECU will constantly ping the left and right upstream O2 sensors, and you will see this when watching the trims. If your trim is bouncing around 5 for example, and then it ramps up to 10 or 12 on one side or the other, you have to learn to ignore that. It will quickly settle back down and then the other side will do the same, so it is a back and forth, and up and down trim fluctuation. I normally select only bank 1 short and long term trims to view rather than both banks for initial adjustments.

Now that the engine is started and idling, you want to see where the fuel trims are at. Again, let it run for a few minutes to stabilize. If you see a negative short term trim value of –10% and a negative long term trim value of –15%, the combined value is -25%. The map is far too rich at idle.   If this is the case, your injector percent value is likely to be too small as we are not removing enough of the base fuel pulse. You will want to up this value, say from the original 50% to a value of 55%. When you make the change, you will see the short term trim quickly jump to a positive state. Again, get into the habit of “SAVE” then “WRITE”.

Let it stabilize, and after a few minutes, you should see the long term trims start to change to a less negative value as well as the short term value decreasing as well. One offsets the other, so the goal is to slowly work the idle map to get the idle trims to cancel each other out as much as possible. If you can get it to come in below +/- 10 this is good, if you get it between +/- 5 to +/- 10 this is great. Remember the ECU will be pinging the O2 sensors so the short term trims will be swinging +/- all the while. You just need to recognize and ignore this and look at the value it settles back to.

Once you have the idle trims down, now it is time to start driving the car around and monitoring the vacuum range. You will find certain cells that you will need to tweak a bit here and there. Proceed with caution as you work through the vacuum range. Take small steps here and progressively move to higher load levels in the map.

Keep in mind that your original injectors would never have been run over 80% duty cycle. So at full load and wide open throttle, the max pulse likely from the ECU would be 16 ms. With a 50% larger value in the software, you would be seeing an 8 ms pulse (plus any base offset value) to the injector if no additional ms value was added in the fuel map at wide open throttle. This alone would match factory performance in the vacuum state, and the fuel trims based on O2 sensor closed loop feedback is going to drive the fuel to a 14.7 AFR. Watching the trims will tell you where you need to tweak the map in the vacuum range.

Eventually you are going to reach the boost area of the map. Once you cross the threshold, you are going to start adding more injector pulse width. If your injectors are not greatly oversized for the amount of boost you intend to run, the max amount of injector pulse width addition you will run is likely around an additional 8 ms.

With a 50% larger injector, .50 ms = 2.5% fuel increase. For a 50% larger injector, 8 ms would equal a 40% increase in fuel. This will likely be quite rich on the top end, but better rich than lean to start off. As you go into boost, now you are going to be gauging your settings from your AFR readings to get the desired AFR, and not the fuel trims.

If you take the 8 ms value and plug that into the load pressure (10 psi for example) that equates to the injector sizing calculations and then interpolate that back down to the cell in the vacuum range just prior to boost, this will give you a base fuel curve to work from.

Work in small increments, and progressively move to higher pressures.

Take note that when the vehicle goes into boost, it will not immediately switch out of Closed Loop mode to Open Loop mode. This is where we take control of the O2 sensors and inject a value that tells the ECU that it is lean so it will apply additional fuel correction during the transition period. Generally a value of .49 volts works well to start with. If your forced induction system has the ability control the amount of boost generated (electronic boost control for example) in a light load situation (part throttle), as soon as you enter into boost, you should see your AFR's drop based on the O2 sensor control. 12.2 – 12.4 is a safe value for low boost pressures in the 2 - 4 psi range.

At some point near full throttle your scan tool will report that the ECU has switched

into OPEN LOOP mode. Once it has switched to OPEN LOOP, you must rely on the wideband unit to tell you what the Air Fuel Ratio (AFR) is. A good safe value is in the 10.8 – 11.2 range when in Open Loop at full boost.

There will be a “grey” area up the middle diagonal area of the map where some cells will be in CLOSED LOOP and other times it will be in OPEN LOOP. In that area you may need to split the difference in what you need for between a CLOSED LOOP setting and an OPEN LOOP setting.

Whenever working in the OPEN LOOP area of the fuel map, you will want to get cell specific with the values. In most cases, when working in the CLOSED LOOP area of the map, you will have like values in blocks of cells rather than individual cell variations. Later if you find any drivability issues, you may then need to get cell specific in CLOSED LOOP. You will likely be cell specific in the idle vacuum area of the map. Once you feel you have a good base map dialed in, be sure to save a copy of this map as a back up. You may need it later when you forget and overwrite values by accident.

Gear Selection:

When performing full throttle power tuning, gear selection can make a difference. What you may notice is that if you start with 1st and run through all the gears that the lower gears may look a little lean on a wideband unit. There is not much load on the engine in low gears and you can’t get a very good reading on a wideband unit in the short time it will be in the lower gears.

You want things to settle down some so you can get decent data to work from. Loading the drivetrain so it will not accelerate so fast will provide you better data. 3rd gear on most autos, and 3rd and 4th gear on most manuals will give you the best tuning result.

Altitude Changes:

Since the iEMS3 does not write to the ECU, nor does it turn off or modify ECU functions and parameters, the original adaptives that provide correction for altitude changes will still function as designed to vary the base injector fuel pulse to accommodate for altitude changes. It is a good idea to monitor significant altitude changes as you may need to tweak things a bit here or there if a particular area of the fuel map is causing elevated fuel trim changes in Closed Loop. Over time, the closed loop fuel changes will spill over into long term corrections for the Open Loop fuel tables.

Temperature Changes:

Temperature changes affect the tune much like altitude changes, but not as drastically. When the ambient temperature is very hot outside, this will result in a less dense air charge and may be seen as less boost or manifold pressure. The opposite will take place when the ambient temperature drops. Cooler more dense air can result in greater boost or manifold pressure.

As with altitude changes above, the vehicle ECU is still able to detect and accommodate fuel trims for colder (need more fuel) and warmer (need less fuel) conditions for the base injector pulse.

The iEMS3 does have a temperature based adaptive available that can be used to help fine tune the ECU adaptive fuel trim swings if they are significantly positive or negative. All it does is to minimize the amount of fuel trimming the ECU has to perform.

It is best to start with a tune that is created with ambient conditions around 70 – 75 degrees. This will provide a good middle of the road center point for the ECU adaptives to work from. If the tune was created during hotter or colder conditions, you may want to spend some time tweaking things when you have 70 – 75 degree temperatures outside temperatures. Keep in mind that on a 70 degree day, your Intake Air Temperature is going to be hotter, so use the Intake temperatures as your midpoint for corrections. To use this function, the vehicle Intake Air Temperature sensor (IAT) needs to be tapped into the iEMS3 to provide the temperature reference.

Ignition Retard Map:

It is important to understand how ignition timing works in the ECU. We must also standardize the terminology used to describe knock or ping, and it will fall into the following two categories.

Spark Knock- This is when the fuel/air charge in the combustion chamber is ignited by the spark of the spark plug, but too soon for the conditions. It results in an uneven flame front and you may hear it as a sound commonly called pinging. The important thing to grasp is that the spark of the spark plug starts the process therefore tuning can address this problem.

Detonation- This is a condition where the fuel/air charge in the combustion chamber is ignited by something other than the spark of the spark plug. This can be extreme heat, too much boost, carbon build up, low fuel quality, and so on. The important thing to grasp is that the spark of the spark plug does not ignite it.

If you are having true detonation, you have a very serious condition and should

expect a catastrophic engine failure in a short time if you allow it to go unchecked. It is likely going to take more then tuning to address it and will most likely require hardware changes like reducing boost, lowering compression and so on. This should not be an issue for most people.

The ECU will always try to run the ignition timing as far advanced as possible. It will keep advancing it until it sees some knock from the knock sensors and then pull the timing back until it stops, then it will start advancing it again until it knocks and so on. This process is going on constantly and it is dynamic meaning it is always self-adjusting. The ECU will always try to keep the ignition timing at the knock threshold above a certain RPM. This is a normal process.

One of the worst things one can do is to remove this level of engine protection by turning off the knock sensors. A very noisy engine may need some desensitizing of the sensors, but I would never suggest turning them off, in particular on a stock internals engine running boost.

We have seen tuners do this in order to mask the inability to eliminate knock retard timing corrections either because of mechanical issues or that it is a short cut to completing a tune. You have a right to know if this level of protection is modified in some way in your engine. If you are running a custom ECU tune, and you NEVER see any knock retard (you are monitoring your vehicle aren't you?), there is a good chance they are either off or dumbed down. Check the knock sensor voltage with your scan tool, if it just stares at you like it is in a coma; guess what, it is brain dead. I hope you have forged internals.

E85 Ethanol Conversion with the iEMS3

Titania O2 Sensors

A Titania Sensor is a less common type of narrow-band lambda sensor that has a ceramic element made of titanium dioxide (Titania). This type does not generate its own voltage (as does the Zirconia sensor), but changes its electrical resistance in response to the oxygen concentration. The resistance of the Titania is a function of the oxygen partial pressure and the temperature.

Titania is an N-type semiconductor with a structure TiO_{2-x}, therefore, the x defects in the crystal lattice conduct the charge. For fuel-rich exhaust the resistance is low, and for fuel-lean exhaust the resistance is high. The ECU feeds the sensor with a small electrical current and measures the resulting voltage across the sensor, which varies from near 0 volts to about 5 volts. Like the Zirconia sensor, this type is so nonlinear that in practice it is used simply as a binary "rich or lean" indicator. Titania sensors are more expensive than Zirconia sensors, but they also respond faster.

In automotive applications the Titania sensor, unlike the Zirconia sensor, does not require a reference sample of atmospheric air to operate properly. This makes the sensor assembly easier to design against water contamination.

E85 Ethanol

E85 has an octane rating of 105 AKI, which is higher than typical commercial gasoline mixtures (octane ratings of 85 to 98 AKI); however, it does not burn as efficiently in traditional internal-combustion engines. E85 contains less energy per volume as compared to gasoline. Although E85 contains only 72% of the energy on a gallon-for-gallon basis compared to gasoline, experimenters have seen slightly better fuel mileage than the 28% this difference in energy content implies. Recent tests by the National Renewable Energy Lab on fleet vehicles owned by the state of Ohio showed about a 25% reduction in mpg (see table below) comparing E85 operation to reformulated gasoline in the same flexible fuel vehicle. Results compared against a gasoline-only vehicle were essentially the same, about a 25% reduction in volumetric fuel economy with E85.

The main attractions of burning E85 are the common benefits of renewable energy sources, such as increased economic benefits for rural populations, less reliance on foreign energy that keeps more fuel dollars in the domestic economy, with further research into increasing production efficiency, less carbon emissions per unit as compared to conventional fossil fuels.

Modern cars (most cars built after 1988) have fuel-injection engines with oxygen sensors that will attempt to adjust the air-fuel mixture, but the oxygen sensor only changes the air to fuel ratio at idle, and at light cruising speeds (closed loop operation). Since the computer can not add more fuel without the input from the oxygen sensor at high loads (open loop operation), there will be significant power losses in modern cars due to the inability of the ECU to correct the open loop fuel tables to deliver the required amount of fuel per injector pulse.

Operating fuel-injected non-FFVs on more than 50% ethanol will generally cause the Malfunction Indicator Lamp (MIL) to illuminate, indicating that the electronic control unit (ECU) believes that it can no longer maintain closed-loop control of the internal combustion process, **not due to the presence of more oxygen in E85, but rather the fact that E85 has less carbon per volume, thus requiring more fuel than the injector size can deliver versus gasoline.**

In other words, the issue is simply the stock injectors are not sized large enough in a non FFV to allow full compensation by the ECU via the fuel trims once the stock injectors are maxed out.

Under stoichiometric combustion conditions, ideal combustion occurs for burning pure gasoline as well as for various mixes of gasoline and ethanol (at least until the MIL illuminates in the non-FFV) such that there is no significant amount of uncombined oxygen or unburned fuel being emitted in the exhaust.

This means that no change in the exhaust manifold oxygen sensor is required for either FFVs or non-FFVs when burning higher percentages of ethanol. This also means that the catalytic converter on the non-FFV burning ethanol mixed with gasoline is not being stressed by the presence of too much oxygen in the exhaust, which would otherwise reduce catalytic converter operating life.

For non-FFVs burning E85 once the MIL illuminates, **it is the undersized amount of fuel injection than what is needed** that causes the air fuel mixture to become too lean; that is, there is not enough fuel being injected into the combustion process, with the result that the oxygen content in the exhaust rises out of limits, and perfect (i.e., stoichiometric) combustion is lost if the percentage of ethanol in the fuel tank becomes too high. It is the loss of near-stoichiometric combustion that causes the excessive loss of fuel economy in non-FFVs burning too high a percentage of ethanol versus gasoline in their fuel mix.

E85 and Forced Induction

E85 gives particularly good results in turbocharged cars due to its high octane. It allows the ECU to run more favorable ignition timing and leaner fuel mixtures than are possible on normal premium gasoline. Users who have experimented with converting OBDII (i.e., On-Board Diagnostic System 2, that is for 1996 model year and later) turbocharged cars to run on E85 have had very good results.

Experiments indicate that most OBDII-specification turbocharged cars can run up to approximately 39% E85 (33% ethanol) with no MILs or other problems. (In contrast, most OBDII specification fuel-injected non-turbocharged cars and light trucks are more forgiving and can usually operate well with in excess of 50% E85 (42% ethanol) prior to having MILs occur.) Fuel system compatibility issues have not been reported for any OBDII cars or light trucks running on high ethanol mixes of E85 and gasoline for periods of time exceeding two years. (This is likely to be the outcome justifiably expected of the normal conservative automotive engineer's predisposition not to design a fuel system merely resistant to ethanol in E10, or 10% percentages, but instead to select materials for the fuel system that are nearly impervious to ethanol.)

Fuel economy does not drop as much as might be expected in turbocharged engines based on the specific energy content of E85 compared to gasoline, in contrast to the previously-reported reduction of 23.7% reduction in a 60:40 blend of gasoline to E85 for one non-turbocharged, fuel-injected, non-FFV. The reason for this non-intuitive difference is that the turbocharged engine seems especially well-suited for operation on E85, for it in effect has a variable compression ratio capability, which is exactly what is needed to accommodate varying ethanol and gasoline ratios that occur in practice in an FFV.

At light load cruise, the turbocharged engine operates as a low compression engine. Under high load and high manifold boost pressures, such as accelerating to pass or merge onto a highway, it makes full use of the higher octane of E85. It appears that due to the better ignition timing and better engine performance on a fuel of 100

octane, the driver spends less time at high throttle openings, and can cruise in a higher gear and at lower throttle openings than is possible on 100% premium gasoline. In daily commute driving, mostly highway, 100% E85 in a turbocharged car can hit fuel mileages of over 90% of the normal gasoline fuel economy. Tests indicate approximately a 5% increase in engine performance is possible by switching to E85 fuel in high performance cars.

No significant ignition timing changes are required for a gasoline engine running on E85.

Air/Fuel mixture problems

Running a non-FFV with a high percentage of ethanol will cause the air fuel mixture to be leaner than normal in **open loop fuel injection engines**, and cause closed loop fuel injection systems to adjust for the increase in oxygen content of the fuel mixture. A lean mixture, when leaner than stoichiometric, could cause heat related engine damage because combustion chamber temperatures can increase with a surplus of air during the combustion event. Some aftermarket E85 conversion kits for modern fuel injected vehicles operate by altering the duty cycles of electronic injectors to help offset air/fuel mixture issues.

Closed loop fuel injection systems eliminate much of the risk. This is also why the check engine light will illuminate if you mix more than around 50% to 60% E85 by volume with your gasoline in a non-FFV. If this happens, just add more 87 octane regular grade gasoline as soon as possible to correct the problem. (Some premium blends contain up to 10% ethanol; to correct the problem as quickly as possible, always add regular grade gasoline, not premium grade gasoline.) These fuel/air mixture related problems will not happen in a properly-converted vehicle.

After-market conversions

There are E85 conversion kits available that will permit the conversion of 4, 6, or 8 cylinder engines to operate from fuels ranging from pure gasoline to a mix of gasoline and ethanol to pure ethanol, including E85. It operates by modifying the fuel-injection pulses sent to the fuel injectors when in 'A', or ethanol mode instead of 'G', or gasoline mode. (In 'G' mode, no modification to the fuel-injection pulses is performed.) This conversion kit modification serves to extend the control range over which the ECU can adjust the air-fuel ratio to achieve an oxygen sensor reading measured before the catalytic converter that falls within nominal stoichiometric ideal combustion limits. The general belief is that this conversion kit operates in its 'A' mode simply through lengthening the individual pulse-widths of fuel-injection pulses, thereby increasing fuel flow per injection pulse by roughly 30%, whereas in 'G' mode, it acts simply as a straight pass through for fuel-injection pulses.

Air fuel ratio comparison

E85 fuel requires a richer air fuel mixture than gasoline for best results. Successful conversions generally require up to 60% more fuel flow than when the engine burns

100% gasoline. (In contrast, methanol conversions require even more fuel flow increase than ethanol conversions.) Flexible fuel vehicles additionally impose a wider range of air fuel ratios that must be achieved than what is required for vehicles that operate only on gasoline or ethanol. This is because a wider range of air fuel ratios is required to use all the varying percentages of ethanol and gasoline efficiently that may be present in the fuel tank at any given time.

The nominal (chemically correct) air fuel ratio is 14.64:1 by mass (not volume) for burning 100% gasoline, but in practice the nominal air fuel ratio for most 100% gasoline fuel injection systems ranges from about 14.6 to 14.7 for a typical nominal value, depending on manufacturer, with the ratio of 14.7 being slightly preferred for increasing fuel economy under light load conditions.

The following table shows the range of air fuel ratios typically used for burning gasoline, E85, and pure ethanol (E100) under an assortment of assumed operating conditions:

Fuel	AFR	Equivalence Ratio	Lambda
Gasoline stoichiometric	14.7	1	1
Gasoline max power rich	12.5	1.176	0.8503
Gasoline max power lean	13.23	1.111	0.900
E85 stoichiometric	9.765	1	1
E85 max power rich	6.975	1.40	0.7143
E85 max power lean	8.4687	1.153	0.8673

The term AFRst refers to the air fuel ratio under stoichiometric or ideal air fuel ratio mixture conditions. Equivalence ratio is the ratio of actual fuel air ratio to stoichiometric fuel air ratio; it provides an intuitive way to express richer mixtures. Lambda (λ) is the ratio of actual air fuel ratio to stoichiometric air fuel ratio; it provides an intuitive way to express leanness conditions (i.e., less fuel, less rich) mixtures of fuel and air.

At inlet air temperatures below 15 ℃ (59 ℉), it i s likewise not possible to start the typical internal combustion engine on pure ethanol (E100); for cold engine starts, starting the engine on gasoline and then shifting to E100 can be done. Similarly, for starting a vehicle on E85 summer blend in extremely cold weather, it is likewise required to add additional gasoline during at least the starting of the engine, before switching to burning the E85 summer blend. In practice, it is easier simply to add more pure gasoline to the fuel tank when extremely cold weather is expected, prior to the arrival of the cold weather, to avoid cold engine start difficulties.

Fortunately for those converting non-FFVs to operate on E85, the wide range of inherent air fuel control required for burning pure gasoline is very nearly the same range required for burning many blends of E85 with gasoline up to approximately 60% E85, at least for non-extreme engine loads and non-extreme weather conditions. Hence, the common success seen in practice for burning many blends of E85 with gasoline even in non-FFVs at blends in excess of 50% E85, especially under light engine loads cruising under benign weather conditions.

Additionally, the ideal stoichiometric mixture typically burns too hot for any situation other than light load cruise (closed loop operation). This is the target mixture that the ECU attempts to achieve in closed-loop fueling to get the best possible emissions and fuel mileage at light load cruise conditions. This mixture typically can give approximately 95% of the engine's best power, provided the fuel has sufficient octane to prevent damaging detonation (i.e., knock).

The "max power rich" condition is the richest air fuel mixture (more fuel than best power) that gives both good drivability and power levels, within approximately 1% of the absolute best power on that fuel.

The "max power lean" condition is the leanest air fuel mixture (less fuel than best power) that gives good drivability, acceptable exhaust gas temperatures to prevent engine damage, and power levels within approximately 1% of the absolute best power on that fuel.

Lambda, typically used for referring to lean versus rich air fuel mixtures, is normally measured by the lambda sensor] (also known as an oxygen sensor.)

iEMS3 and E85 Conversion

The modern OBDII vehicles closed loop fuel system is fully capable of correcting for the additional fuel requirements up to the point where the ECU adaptive fuel trims max out based on the stock injector size and duty cycle.

Keep in mind, the O2 sensor is measuring oxygen concentration, and it will adjust the fuel trims to achieve the 1 to 1 Lambda ratio regardless of the fuel used. If you are running a wideband sensor, and set the display scaling to Lambda in lieu of gasoline AFR, you will see the Lambda value as 1 in closed loop operation. It is easier to understand if you think of this in the Lambda value rather than specific fuel AFR values.

So the problem running E85 in non FFV's is simply the maximum amount of fuel that can be injected via the stock fuel injectors. Generally an FFV has 30% larger injectors installed, and the ECU maps scaled accordingly from the factory. In a non FFV in open loop mode without the o2 sensor feedback, a stock vehicle will see a very lean condition as the ECU is not able to add additional injector pulse width to the values in the open loop fuel tables as it can via the fuel trims in closed loop operation.

The iEMS3 has the capabilities to scale the injector pulse widths to extend the adaptive trim range in closed loop operation, and to extend the injector fuel pulse in open loop, thereby allowing convenient and effective use of E85 rather for purely environmental desires (a more green footprint) or to take advantage of the higher octane ratings and cooling effects of burning E85. In addition, the iEMS3 has the ability to be tied into an engine coolant sensor to allow application of a cold start fuel delivery increase to assist in cold weather operation. As the engine warms, the additional injector pulse width is lowered back to the normal programmed pulse width during normal operation.

Detonation and Pre Ignition, causes and effects by *Allen W. Cline*

All high output engines are prone to destructive tendencies as a result of over boost, misfueling, mis-tuning and inadequate cooling. The engine community pushes ever nearer to the limits of power output. As they often learn cylinder chamber combustion processes can quickly gravitate to engine failure. This article defines two types of engine failures, detonation and pre-ignition that is as insidious in nature to users as they are hard to recognize and detect. This discussion is intended only as a primer about these combustion processes since whole books have been devoted to the subject.

First, let us review normal combustion. It is the burning of a fuel and air mixture charge in the combustion chamber. It should burn in a steady, even fashion across the chamber, originating at the spark plug and progressing across the chamber in a three dimensional fashion. Similar to a pebble in a glass smooth pond with the ripples spreading out, the flame front should progress in an orderly fashion. The burn moves all the way across the chamber and , quenches (cools) against the walls and the piston crown. The burn should be complete with no remaining fuel-air mixture. Note that the mixture does not "explode" but burns in an orderly fashion.

There is another factor that engineers look for to quantify combustion. It is called "location of peak pressure (LPP)." It is measured by an in-cylinder pressure transducer. Ideally, the LPP should occur at 14 degrees after top dead center. Depending on the chamber design and the burn rate, if one would initiate the spark at its optimum timing (20 degrees BTDC, for example) the burn would progress through the chamber and reach LPP, or peak pressure at 14 degrees after top dead center. LPP is a mechanical factor just as an engine is a mechanical device. The piston can only go up and down so fast. If you peak the pressure too soon or too late in the cycle, you won't have optimum work. Therefore, LPP is always 14 degrees ATDC for any engine.

I introduce LPP now to illustrate the idea that there is a characteristic pressure buildup (compression and combustion) and decay (piston downward movement and exhaust valve opening) during the combustion process that can be considered "normal" if it is smooth, controlled and its peak occurs at 14 degrees ATDC.

Our enlarged definition of normal combustion now says that the charge/bum is initiated with the spark plug, a nice even burn moves across the chamber, combustion is completed and peak pressure occurs at 14 ATDC.

Confusion and a lot of questions exist as to **detonation** and **pre-ignition**. Sometimes you hear mistaken terms like "pre-detonation". Detonation is one phenomenon that is abnormal combustion. Pre-ignition is another phenomenon that is abnormal combustion. The two, as we will talk about, are somewhat related but are two distinctly different phenomenon and can induce distinctly different failure modes.

Key Definitions

Detonation

> Detonation is the spontaneous combustion of the end-gas (remaining fuel/air mixture) in the chamber. It always occurs after normal combustion is initiated by the spark plug. The initial combustion at the spark plug is followed by a normal combustion burn. For some reason, likely heat and pressure, the end gas in the chamber spontaneously combusts. The key point here is that detonation occurs after you have initiated the normal combustion with the spark plug.

Pre-ignition

> Pre-ignition is defined as the ignition of the mixture prior to the spark plug firing. Anytime something causes the mixture in the chamber to ignite **prior** to the spark plug event it is classified as pre-ignition. The two are completely different and abnormal phenomenon.

Detonation

Unburned end gas, under increasing pressure and heat (from the normal progressive burning process and hot combustion chamber metals) spontaneously combusts, ignited solely by the intense heat and pressure. The remaining fuel in the end gas simply lacks sufficient octane rating to withstand this combination of heat and pressure.

Detonation causes a very high, very sharp pressure spike in the combustion chamber but it is of a very short duration. If you look at a pressure trace of the combustion chamber process, you would see the normal burn as a normal pressure rise, then all of a sudden you would see a very sharp spike when the detonation occurred. That spike always occurs after the spark plug fires. The sharp spike in pressure creates a force in the combustion chamber. It causes the structure of the engine to ring, or resonate, much as if it were hit by a hammer. Resonance, which is characteristic of combustion detonation, occurs at about 6400 Hertz. So the pinging you hear is actually the structure of the engine reacting to the pressure spikes. This

noise of detonation is commonly called spark knock. This noise changes only slightly between iron and aluminum. This noise or vibration is what a knock sensor picks up. The knock sensors are tuned to 6400 hertz and they will pick up that spark knock. Incidentally, the knocking or pinging sound is not the result of "two flame fronts meeting" as is often stated. Although this clash does generate a spike the noise you sense comes from the vibration of the engine structure reacting to the pressure spike.

One thing to understand is that detonation is not necessarily destructive. Many engines run under light levels of detonation, even moderate levels. Some engines can sustain very long periods of heavy detonation without incurring any damage. If you've driven a car that has a lot of spark advance on the freeway, you'll hear it pinging. It can run that way for thousands and thousands of miles. Detonation is not necessarily destructive. It's not an optimum situation but it is not a guaranteed instant failure. The higher the specific output (HP/in3) of the engine, the greater the sensitivity to detonation. An engine that is making 0.5 HP/in3 or less can sustain moderate levels of detonation without any damage; but an engine that is making 1.5 HP/in3, if it detonates, it will probably be damaged fairly quickly, here I mean within minutes.

Detonation causes three types of failure:

1. Mechanical damage (broken ring lands)
2. Abrasion (pitting of the piston crown)
3. Overheating (scuffed piston skirts due to excess heat input or high coolant temperatures)

The high impact nature of the spike can cause fractures; it can break the spark plug electrodes, the porcelain around the plug, cause a clean fracture of the ring land and can actually cause fracture of valves-intake or exhaust. The piston ring land, either top or second depending on the piston design, is susceptible to fracture type failures. If I were to look at a piston with a second broken ring land, my immediate suspicion would be detonation.

Another thing detonation can cause is a sandblasted appearance to the top of the piston. The piston near the perimeter will typically have that kind of look if detonation occurs. It is a swiss-cheesy look on a microscopic basis. The detonation, the mechanical pounding, actually mechanically erodes or fatigues material out of the piston. You can typically expect to see that sanded look in the part of the chamber most distant from the spark plug, because if you think about it, you would ignite the flame front at the plug, it would travel across the chamber before it got to the farthest reaches of the chamber where the end gas spontaneously combusted. That's where you will see the effects of the detonation; you might see it at the hottest part of the chamber in some engines, possibly by the exhaust valves. In that case the end gas was heated to detonation by the residual heat in the valve.

In a four valve engine with a pent roof chamber with a spark plug in the center, the chamber is fairly uniform in distance around the spark plug. But one may still may see detonation by the exhaust valves because that area is usually the hottest part of the chamber. Where the end gas is going to be hottest is where the damage, if any, will occur.

Because this pressure spike is very severe and of very short duration, it can actually shock the boundary layer of gas that surrounds the piston. Combustion temperatures exceed 1800 degrees. If you subjected an aluminum piston to that temperature, it would just melt. The reason it doesn't melt is because of thermal inertia and because there is a boundary layer of a few molecules thick next to the piston top. This thin layer isolates the flame and causes it to be quenched as the flame approaches this relatively cold material. That combination of actions normally protects the piston and chamber from absorbing that much heat. However, under extreme conditions the shock wave from the detonation spike can cause that boundary layer to breakdown which then lets a lot of heat transfer into those surfaces.

Engines that are detonating will tend to overheat, because the boundary layer of gas gets interrupted against the cylinder head and heat gets transferred from the combustion chamber into the cylinder head and into the coolant. So it starts to overheat. The more it overheats, the hotter the engine, the hotter the end gas, the more it wants to detonate, the more it wants to overheat. It's a snowball effect. That's why an overheating engine wants to detonate and that's why engine detonation tends to cause overheating.

Many times you will see a piston that is scuffed at the "four corners". If you look at the bottom side of a piston you see the piston pin boss. If you look across each pin boss it's solid aluminum with no flexibility. It expands directly into the cylinder wall. However, the skirt of a piston is relatively flexible. If it gets hot, it can deflect. The crown of the piston is actually slightly smaller in diameter on purpose so it doesn't contact the cylinder walls. So if the piston soaks up a lot of heat, because of detonation for instance, the piston expands and drives the piston structure into the cylinder wall causing it to scuff in four places directly across each boss. It's another dead give-a-way sign of detonation. Many times detonation damage is just limited to this.

Some engines, such as liquid cooled 2-stroke engines found in snowmobiles, watercraft and motorcycles, have a very common detonation failure mode. What typically happens is that when detonation occurs the piston expands excessively, scurfs in the bore along those four spots and wipes material into the ring grooves. The rings seize so that they can't conform to the cylinder walls. Engine compression is lost and the engine either stops running, or you start getting blow-by past the rings. That torches out an area. Then the engine quits.

In the shop someone looks at the melted result and says, "pre-ignition damage". No, it's detonation damage. Detonation caused the piston to scuff and this snowballed into loss of compression and hot gas escaping by the rings that caused the melting.

Once again, detonation is a source of confusion and it is very difficult, sometimes, to pin down what happened, but in terms of damage caused by detonation, this is another typical sign.

While some of these examples may seem rather tedious I mention them because a "scuffed piston" is often blamed on other factors and detonation as the problem is overlooked. A scuffed piston may be an indicator of a much more serious problem which may manifest itself the next time with more serious results.

In the same vein, an engine running at full throttle may be happy due to a rich WOT air/fuel ratio. Throttling back to part throttle the mixture may be leaner and detonation may now occur. Bingo, the piston overheats and scuffs, the engine fails but the postmortem doesn't consider detonation because the the failure didn't happen at WOT.

I want to reinforce the fact that the detonation pressure spike is very brief and that it occurs after the spark plug normally fires. In most cases that will be well after ATDC, when the piston is moving down. You have high pressure in the chamber anyway with the burn. The pressure is pushing the piston like it's supposed to, and superimposed on that you get a brief spike that rings the engine.

Causes

Detonation is influenced by chamber design (shape, size, geometry, plug location), compression ratio, engine timing, mixture temperature, cylinder pressure and fuel octane rating. Too much spark advance ignites the burn too soon so that it increases the pressure too greatly and the end gas spontaneously combusts. Backing off the spark timing will stop the detonation. The octane rating of the fuel is really nothing magic. Octane is the ability to resist detonation. It is determined empirically in a special running test engine where you run the fuel, determine the compression ratio that it detonates at and compare that to a standard fuel, That's the octane rating of the fuel. A fuel can have a variety of additives or have higher octane quality. For instance, alcohol as fuel has a much better octane rating just because it cools the mixture significantly due to the extra amount of liquid being used. If the fuel you got was of a lower octane rating than that demanded by the engine's compression ratio and spark advance detonation could result and cause the types of failures previously discussed.

Production engines are optimized for the type or grade of fuel that the marketplace desires or offers. Engine designers use the term called MBT (Minimum spark for Best Torque) for efficiency and maximum power; it is desirable to operate at MBT at all times. For example, let's pick a specific engine operating point, 4000 RPM, WOT, 98 kPa MAP. At that operating point with the engine on the dynamometer and using non-knocking fuel, we adjust the spark advance. There is going to be a point where the power is the greatest. Less spark than that, the power falls off, more spark advance than that, you don't get any additional power.

Now our engine was initially designed for premium fuel and was calibrated for 20 degrees of spark advance. Suppose we put regular fuel in the engine and it spark knocks at 20 degrees? We back off the timing down to 10 degrees to get the detonation to stop. It doesn't detonate any more, but with 10 degrees of spark retard, the engine is not optimized anymore. The engine now suffers about a 5-6 percent loss in torque output. That's an unacceptable situation. To optimize for regular fuel engine designers will lower the compression ratio to allow an increase in the spark advance to MBT. The result, typically, is only a 1-2 percent torque loss by lowering the compression. This is a better trade-off. Engine test data determines how much compression an engine can have and run at the optimum spark advance.

For emphasis, the design compression ratio is adjusted to maximize efficiency/power on the available fuel. Many times in the aftermarket the opposite occurs. A compression ratio is "picked" and the end user tries to find good enough fuel and/or retards the spark to live with the situation...or suffers engine damage due to detonation.

Another thing you can do is increase the burn rate of the combustion chamber. That is why with modem engines you hear about fast burn chambers or quick burn chambers. The goal is the faster you can make the chamber burn, the more tolerant to detonation it is. It is a very simple phenomenon, the faster it burns, the quicker the burn is completed, the less time the end gas has to detonate. If it can't sit there and soak up heat and have the pressure act upon it, it can't detonate.

If, however, you have a chamber design that burns very slowly, like a mid-60s engine, you need to advance the spark and fire at 38 degrees BTDC. Because the optimum 14 degrees after top dead center (LPP) hasn't changed the chamber has far more opportunity to detonate as it is being acted upon by heat and pressure. If we have a fast burn chamber, with 15 degrees of spark advance, we've reduced our window for detonation to occur considerably. It's a mechanical phenomenon. That's one of the goals of having a fast burn chamber because it is resistant to detonation.

There are other advantages too, because the faster the chamber burns, the less spark advance you need. The less time pistons have to act against the pressure build up, the air pump becomes more efficient. Pumping losses are minimized. In other words, as the piston moves towards top dead center compression of the fuel/air mixture increases. If you light the fire at 38 degrees before top dead center, the piston acts against that pressure for 38 degrees. If you light the spark 20 degrees before top dead center, it's only acting against it for 20. The engine becomes more mechanically efficient.

There are a lot of reasons for fast burn chambers but one nice thing about them is that they become more resistant to detonation. A real world example is the Northstar engine from 1999 to 2000. The 1999 engine was a 10.3:1 compression ratio. It was a premium fuel engine. For the 2000 model year, we revised the combustion chamber, achieved faster bum. We designed it to operate on regular fuel and we only had to lower the compression ratio .3 to only 10:1 to make it work. Normally, on a given engine (if you didn't change the combustion chamber design) to go from

premium to regular fuel, it will typically drop one point in compression ratio: With our example, you would expect a Northstar engine at 10.3:1 compression ratio, dropped down to 9.3:1 in order to work on regular. Because of the faster burn chamber, we only had to drop to 10:1. The 10:1 compression ratio still has very high compression with attendant high mechanical efficiency and yet we can operate it at optimum spark advance on regular fuel. That is one example of spark advance in terms of technology. A lot of that was achieved through computational fluid dynamics analysis of the combustion chamber to improve the swirl and tumble and the mixture motion in the chamber to enhance the bum rate.

Chamber Design

One of the characteristic chambers that people are familiar with is the Chrysler Hemi. The engine had a chamber that was like a half of a baseball. Hemispherical in nature and in nomenclature, too. The two valves were on either side of the chamber with the spark plug at the very top. The charge burned downward across the chamber. That approach worked fairly well in passenger car engines but racing versions of the Hemi had problems. Because the chamber was so big and the bores were so large, the chamber volume also was large; it was difficult to get the compression ratio high. Racers put a dome on the piston to increase the compression ratio. If you were to take that solution to the extreme and had a 13:1 or 14:1 compression ratio in the engine pistons had a very tall dome. The piston dome almost mimicked the shape of the head's combustion chamber with the piston at top dead center. One could call the remaining volume "the skin of the orange." When ignited the charge burned very slowly, like the ripples in a pond,, covering the distance to the block cylinder wall. Thus, those engines, as a result of the chamber design, required a tremendous amount of spark advance, about 40-45 degrees. With that much spark advance detonation was a serious possibility if not fed high octane fuel. Hemis tended to be very sensitive to tuning. As often happened, one would keep advancing the spark, get more power and all of a sudden the engine would detonate, Because they were high output engines, turning at high RPM, things would happen suddenly.

Hemi racing engines would typically knock the ring land off, get blow by, torch the piston and fall apart. No one then understood why. We now know that the Hemi design is at the worst end of the spectrum for a combustion chamber. A nice compact chamber is best; that's why the four valve pent roof style chambers are so popular. The flatter the chamber, the smaller the closed volume of the chamber, the less dome you need in the piston. We can get inherently high compression ratios with a flat top piston with a very nice bum pattern right in the combustion chamber, with very short distances, with very good mixture motion - a very efficient chamber.

Look at a Northstar or most of the 4 valve type engines - all with flat top pistons, very compact combustion chambers, very narrow valve angles and there is no need for a dome that impedes the burn to raise the compression ratio to 10:1.

Detonation Indicators

The best indication of detonation is the pinging sound that cars, particularly old models, make at low speeds and under load. It is very difficult to hear the sound in well insulated luxury interiors of today's cars. An unmuffled engine running straight pipes or a propeller turning can easily mask the characteristic ping. The point is that you honestly don't know that detonation is going on. In some cases, the engine may smoke but not as a rule. Broken piston ring lands are the most typical result of detonation but are usually not spotted. If the engine has detonated visual signs like broken spark plug porcelains or broken ground electrodes are dead giveaways and call for further examination or engine disassembly.

It is also very difficult to sense detonation while an engine is running in an remote and insulated dyno test cell. One technique seems almost elementary but, believe it or not, it is employed in some of the highest priced dyno cells in the world. We refer to it as the "Tin Ear". You might think of it as a simple stethoscope applied to the engine block. We run a ordinary rubber hose from the dyno operator area next to the engine. To amplify the engine sounds we just stick the end of the hose through the bottom of a Styrofoam cup and listen in! It is common for ride test engineers to use this method on development cars particularly if there is a suspicion out on the road borderline detonation is occurring. Try it on your engine; you will be amazed at how well you can hear the different engine noises.

The other technique is a little more subtle but usable if attention is paid to EGT (Exhaust Gas Temperature). Detonation will actually cause EGTs to drop. This behavior has fooled a lot of people because they will watch the EGT and think that it is in a low enough range to be safe, the only reason it is low is because the engine is detonating.

The only way you know what is actually happening is to be very familiar with your specific engine EGT readings as calibrations and probe locations vary. If, for example, you normally run 1500 degrees at a given MAP setting and you suddenly see 1125 after picking up a fresh load of fuel you should be alert to possible or incipient detonation. Any drop from normal EGT should be reason for concern. Using the "Tin Ear" during the early test stage and watching the EGT very carefully, other than just plain listening with your ear without any augmentation, is the only way to identify detonation. The good thing is, most engines will live with a fairly high level of detonation for some period of time. It is not an instantaneous type failure.

Pre-Ignition

The definition of pre-ignition is the ignition of the fuel/air charge prior to the spark plug firing. Pre-ignition caused by some other ignition source such as an overheated spark plug tip, carbon deposits in the combustion chamber and, rarely, a burned exhaust valve; all act as a glow plug to ignite the charge.

Keep in mind the following sequence when analyzing pre-ignition. The charge enters the combustion chamber as the piston reaches BDC for intake; the piston next reverses direction and starts to compress the charge. Since the spark voltage requirements to light the charge increase in proportion with the amount of charge compression; almost anything can ignite the proper fuel/air mixture at BDC!! BDC or before is the easiest time to light that mixture. It becomes progressively more difficult as the pressure starts to build.

A glowing spot somewhere in the chamber is the most likely point for pre-ignition to occur. It is very conceivable that if you have something glowing, like a spark plug tip or a carbon ember, it could ignite the charge while the piston is very early in the compression stoke. The result is understandable; for the entire compression stroke, or a great portion of it, the engine is trying to compress a hot mass of expanded gas. That obviously puts tremendous load on the engine and adds tremendous heat into its parts. Substantial damage occurs very quickly. You can't hear it because there is no rapid pressure rise. This all occurs well before the spark plug fires.

Remember, the spark plug ignites the mixture and a sharp pressure spike occurs after that, when the detonation occurs. That's what you hear. With pre-ignition, the ignition of the charge happens far ahead of the spark plug firing, in my example, very, very far ahead of it when the compression stroke just starts. There is no very rapid pressure spike like with detonation. Instead, it is a tremendous amount of pressure which is present for a very long dwell time, i.e., the entire compression stroke. That's what puts such large loads on the parts. There is no sharp pressure spike to resonate the block and the head to cause any noise. So you never hear it, the engine just blows up! That's why pre-ignition is so insidious. It is hardly detectable before it occurs. When it occurs you only know about it after the fact. It causes a catastrophic failure very quickly because the heat and pressures are so intense.

An engine can live with detonation occurring for considerable periods of time, relatively speaking. There are no engines that will live for any period of time when pre-ignition occurs. When people see broken ring lands they mistakenly blame it on pre-ignition and overlook the hammering from detonation that caused the problem. A hole in the middle of the piston, particularly a melted hole in the middle of a piston, is due to the extreme heat and pressure of pre-ignition.

Other signs of pre-ignition are melted spark plugs showing splattered, melted, fused looking porcelain. Many times a "pre-ignited plug" will melt away the ground electrode. What's left will look all spattered and fuzzy looking. The center electrode will be melted and gone and its porcelain will be spattered and melted. This is a typical sign of incipient pre-ignition.

The plug may be getting hot, melting and "getting ready" to act as a pre-ignition source. The plug can actually melt without pre-ignition occurring. However, the melted plug can cause pre-ignition the next time around.

The typical pre-ignition indicator, of course, would be the hole in the piston. This occurs because in trying to compress the already burned mixture the parts soak up a tremendous amount of heat very quickly. The only ones that survive are the ones that have a high thermal inertia, like the cylinder head or cylinder wall. The piston, being aluminum, has a low thermal inertia (aluminum soaks up the heat very rapidly). The crown of the piston is relatively thin, it gets very hot, it can't reject the heat, it has tremendous pressure loads against it and the result is a hole in the middle of the piston where it is weakest.

I want to emphasis that when most people think of pre-ignition they generally accept the fact that the charge was ignited before the spark plug fires. However, I believe they limit their thinking to 5-10 degrees before the spark plug fires. You have to really accept that the most likely point for pre-ignition to occur is 180 degrees BTDC, some 160 degrees before the spark plug would have fired because that's the point (if there is a glowing ember in the chamber) when it's most likely to be ignited. We are talking some 160-180 degrees of bum being compressed that would normally be relatively cool. A piston will only take a few revolutions of that distress before it fails. As for detonation, it can get hammered on for seconds, minutes, or hours depending on the output of the engine and the load, before any damage occurs. Pre-ignition damage is almost instantaneous.

When the piston crown temperature rises rapidly it never has time to get to the skirt and expand and cause it to scuff. It just melts the center right out of the piston. That's the biggest difference between detonation and pre-ignition when looking at piston failures. Without a high pressure spike to resonate the chamber and block, you would never hear pre-ignition. The only sign of pre-ignition is white smoke pouring out the tailpipe and the engine quits running.

The engine will not run more than a few seconds with pre-ignition. The only way to control pre-ignition is just keep any pre-ignition sources at bay. Spark plugs should be carefully matched to the recommended heat range. Racers use cold spark plugs and relatively rich mixtures. Spark plug heat range is also affected by coolant temperatures. A marginal heat range plug can induce pre-ignition because of an overheated head (high coolant temperature or inadequate flow). Also, a loose plug can't reject sufficient heat through its seat. A marginal heat range plug running lean (suddenly?) can cause pre-ignition.

Passenger car engine designers face a dilemma. Spark plugs must cold start at -40 degrees F. (which calls for hot plugs that resist fouling) yet be capable of extended WOT operation (which calls for cold plugs and maximum heat transfer to the cylinder head).

Here is how spark plug effectiveness or "pre-ignition" testing is done at WOT. Plug tip/gap temperature is measured with a blocking diode and a small battery supplying current through a milliamp meter to the spark plug terminal. The secondary voltage cannot come backwards up the wire because the large blocking diode prevents it.

As the spark plug tip heats up, it tends to ionize the gap and small levels of current will flow from the battery as indicated by the milliamp gauge. The engine is run under load and the gauges are closely watched. Through experience techni-cians learn what to expect from the gauges. Typically, very light activity, just a few milliamps of current, is observed across the spark plug gap. In instances where the spark plug tip/gap gets hot enough to act as an ignition source the mil-liamp current flow suddenly jumps off scale. When that hap-pens, instant power reduction is necessary to avoid major en-gine damage.

Back in the 80s, running engines that made half a horsepower per cubic inch, we could artificially and safely induce pre-ignition by using too hot of a plug and leaning out the mixture. We could determine how close we were by watching the gauges and had plenty of time (seconds) to power down, before any damage occurred.

With the Northstar making over 1 HP per cubic inch, at 6000 RPM, if the needles move from nominal, you just failed the engine. It's that quick! When you disassemble the engine, you'll find definite evidence of damage. It might be just melted spark plugs. But pre-ignition happens that quick in high output engines. There is very little time to react.

If cold starts and plug fouling are not a major worry run very cold spark plugs. A typical case of very cold plug application is a NASCAR type engine. Because the prime pre-ignition source is eliminated engine tuners can lean out the mixture (some) for maximum fuel economy and add a lot of spark advance for power and even risk some levels of detonation. Those plugs are terrible for cold starting and emissions and they would foul up while you were idling around town but for running at full throttle at 8000 RPM, they function fine. They eliminate a variable that could induce pre-ignition.

Engine developers run very cold spark plugs to avoid the risk of getting into pre-ignition during engine mapping of air/fuel and spark advance, Production engine calibration requires that we have much hotter spark plugs for cold startability and fouling resistance. To avoid pre-ignition we then compensate by making sure the fuel/air calibration is rich enough to keep the spark plugs cool at high loads and at high temperatures, so that they don't induce pre-ignition.

Consider the Northstar engine. If you do a full throttle 0-60 blast, the engine will likely run up to 6000 RPM at a 11.5:1 or 12:1 air fuel ratio. But under sustained load, at about 20 seconds, that air fuel ratio is richened up by the PCM to about 10:1. That is done to keep the spark plugs cool, as well as the piston crowns cool. That richness is necessary if you are running under continuous WOT load. A slight penalty in horsepower and fuel economy is the result. To get the maximum acceleration out of the engine, you can actually lean it out, but under full load, it has to go back to rich. Higher specific output engines are much more sensitive to pre-ignition damage because they are turning more RPM, they are generating a lot more heat and they are burning more fuel. Plugs have a tendency to get hot at that high specific output and reaction time to damage is minimal.

A carburetor set up for a drag racer would never work on a NASCAR or stock car engine because it would overheat and cause pre-ignition. But on the drag strip for 8 or 10 seconds, pre-ignition never has time to occur, so dragsters can get away with it. Differences in tuning for those two different types of engine applications are dramatic. That's why a drag race engine would make a poor choice for an aircraft engine.

Muddy Water

There is a situation called detonation induced pre-ignition. I don't want to sound like double speak here but it does happen. Imagine an engine under heavy load starting to detonate. Detonation continues for a long period of time. The plug heats up because the pressure spikes break down the protective boundary layer of gas surrounding the electrodes. The plug temperature suddenly starts to elevate unnaturally, to the point when it becomes a glow plug and induces pre-ignition. When the engine fails, I categorize that result as "detonation induced pre-ignition." There would not have been any danger of pre-ignition if the detonation had not occurred. Damage attributed to both detonation and pre-ignition would be evident.

Typically, that is what we see in passenger car engines. The engines will typically live for long periods of time under detonation. In fact, we actually run a lot of piston tests where we run the engine at the torque peak, induce moderate levels of detonation deliberately. Based on our resulting production design, the piston should pass those tests without any problem; the pistons should be robust enough to survive. If, however, under circumstances due to overheating or poor fuel, the spark plug tip overheats and induces pre-ignition, it's obviously not going to survive. If we see a failure, it probably is a detonation induced pre-ignition situation.

I would urge any experimenter to be cautious using automotive based engines in other applications. In general, engines producing .5 HP/in3 (typical air-cooled aircraft engines) can be forgiving (as leaning to peak EGT, etc.). But at 1.0 HP/in3 (very typical of many high performance automotive conversions) the window for calibration induced engine damage is much less forgiving. Start out rich, retarded and with cold plugs and watch the EGTs!

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Top Ring End Gap is often a major player when it comes to piston problems. Most top land damage on race pistons appears to lift the land into the combustion chamber. The reason is that the top ring ends butt and lock the piston at TDC. Crank rotation pulls the piston down the cylinder while leaving at least part of the ring and top land at TDC. Actual running end gap will vary depending on the engine heat load. Piston alloy, fuel mixture, spark advance, compression, cooling system capacity, duty cycle, and Hp per c.i. all combine to determine an engine's heat load.

Most new generation pistons incorporate the top compression ring high on the piston. The high ring location cools the piston top more effectively, reduces

detonation, smog, and increases Hp. If detonation or other excess heat situations develop, a top ring end gap set toward the tight side will quickly butt, with piston and cylinder damage to follow immediately. High location rings require extra end gap because they stop at a higher temperature portion of the cylinder at TDC and they have less shielding from the heat of combustion. At TDC the ring is usually above the cylinder water jacket. The current design KB Pistons do a better job of keeping the rings cool.

If a ring end gap is measured on the high side, you improve detonation tolerance in two ways. One, the engine will run longer under detonation before ring butt. Two, some leak down appears to benefit oil control by clearing the rings from oil loading. A small amount of chamber oil will cause detonation and significant Hp loss. The correct top ring end gap with aftermarket pistons can be 50% to 100% more than manufacturer's specs.

To Spray or not to Spray, that is the question!

A discussion on water/methanol injection, air to air, and water to air intercoolers.

You have probably heard of "intercoolers", the big radiator looking device normally seen in the front of a turbocharged, or in some cases supercharged vehicle. But what are they, what do they do, and why are they important? What are the differences, and why does it matter?

In simple terms, the colder the air charge is prior to entering the engine, the less chance for detonation, and a cooler dense air charge will hold more oxygen, meaning more power potential.

Anytime air is compressed, it creates heat and a lot of it. If you have an air compressor at home, you probably know not to touch that copper tube between the compressor and the storage tank after it has pumped up the tank. Why? It will be so hot; you can get second degree burns from it!

A turbocharger or supercharger can easily raise the air temperature in the intake manifold by 100 – 200 degrees or more! This heat is the primary drawback of forced induction, and the more heat we can get rid of, the better the vehicle will perform.

So how do we get rid of this heat energy? That is where 'intercooling" comes into play. But before we discuss it, are we using the right terminology? Well, not exactly, but close.

The ***inter*** prefix in the device name originates from historic compressor designs. In the past, aircraft engines were built with charge air coolers that were installed between multiple stages of supercharging, thus the designation of ***inter,*** meaning between the compressor stages.

Modern automobile designs are technically designated ***aftercoolers*** because of their placement at the end of the forced induction system, or after the last compressor stage. This term is now considered archaic in modern automobile terminology since most forced induction vehicles have single-stage superchargers or turbochargers.

Charge Air Cooler or ***Aftercooler*** would be more appropriate for modern vehicles.

How do they work?

Passing a compressed and heated intake charge through an intercooler reduces its temperature (due to heat rejection) and pressure (due to flow restriction of fins). If properly designed, the net result is an increase in air density. This increases system performance by recovering some losses of the inefficient compression process by rejecting heat to the atmosphere. Additional cooling can be provided by externally spraying a fine mist onto the intercooler surface, or even into the intake air itself, to further reduce intake charge temperature through evaporative cooling.

Intercoolers that exchange their heat directly with the atmosphere are designed to be mounted in areas of an automobile with maximum air flow. These types are mainly mounted in front mounted systems (FMIC), and are considered to be of the Air to Air design.

As well as allowing a greater volume of air to be admitted to an engine, intercoolers have a key role in controlling the internal temperatures in a forced induction engine. When fitted with a turbo (as with any form of supercharging), the engine's specific power is increased, leading to higher combustion and exhaust temperatures. The exhaust gases passing through the turbine section of the turbocharger are usually around 450 ℃ (840 ℉), but can be as high as 1000 ℃ (1830 ℉) under extreme conditions.

This heat passes through the turbocharger unit and contributes to the heating of the air being compressed in the compressor section of the turbo. If left un-cooled this hot air enters the engine, further increasing internal temperatures. This leads to a build up of heat that will eventually stabilize, but this may be at temperatures in excess of the engine's design limits- 'hot spots' at the piston crown or exhaust valve can cause warping or cracking of these components.

This effect is especially found in modified or tuned engines running at very high specific power outputs. An efficient intercooler removes heat from the air in the induction system, preventing the cyclic heat build-up via the turbocharger, allowing higher power outputs to be achieved without damage. The extra power obtained from forced induction is due to the extra air available to burn more fuel in each cylinder. This sometimes requires a lower compression ratio be used, to allow a wider mapping of ignition timing advance before detonation occurs (for a given fuel's octane rating). Although a lower compression ratio generally lowers combustion efficiency and costs power.

Air to Liquid Intercooling

Air-to-liquid intercoolers (Charge-Air-Coolers) are heat exchangers that transfer intake charge heat to an intermediate fluid, usually water, which finally rejects heat to the air. These systems use radiators in other locations, usually due to space constraints, to reject unwanted heat, similar to an automotive radiator cooling system. Air-to-liquid intercoolers are usually heavier than their air-to-air counterparts due to additional components making up the system (water circulation pump, radiator, fluid, and plumbing).

A big advantage of the air-to-liquid setup is the lower overall pipe and intercooler length, which offers less restriction and less pressure drop across the cooler. This helps provide a faster response, giving peak boost faster than most front-mount intercooler setups. Some setups can use reservoirs that can have ice put into it for intake temperatures lower than ambient air, providing an even greater advantage (but of course, ice would need constant replacement, usually only used at a drag strip).

Water has far greater properties to transfer heat than air, so the systems components can be much smaller. It is easier to mount the small radiator where it has less impact on the vehicles radiator, helping to prevent overheating of the vehicle coolant system. Ford adopted the technology when they decided to use forced induction (via Supercharger) on their Mustang Cobra and Ford Lightning truck platforms. It uses a water/glycol mixture intercooler inside the intake manifold, just under the supercharger, and has a long heat exchanger front mounted, all powered by a Bosch pump made for Ford.

Water/Methanol Injection

In internal combustion engines, ***water injection***, also known as ***anti-detonate injection***, is a method for cooling the combustion chambers of engines by adding water to the cylinder or incoming fuel-air mixture, allowing for greater compression ratios and largely eliminating the problem of engine knocking (detonation). This effectively increases the octane rating of the fuel, meaning that performance gains can be obtained when used in conjunction with a supercharger or turbocharger, altered spark ignition timing, and other modifications.

Many water injection systems use a mixture of water and alcohol (approximately 50/50), with trace amounts of water-soluble oil. The water provides the primary cooling effect due to its great density and high heat absorption properties. The alcohol is combustible, and also serves as antifreeze for the water. The purpose of the oil is to prevent corrosion of water injection and fuel system components.

Effects

In a piston engine, the initial injection of water cools the fuel-air mixture significantly, which increases its density and hence the amount of oxygen that enters the cylinder. An additional effect comes later during combustion when the water absorbs large

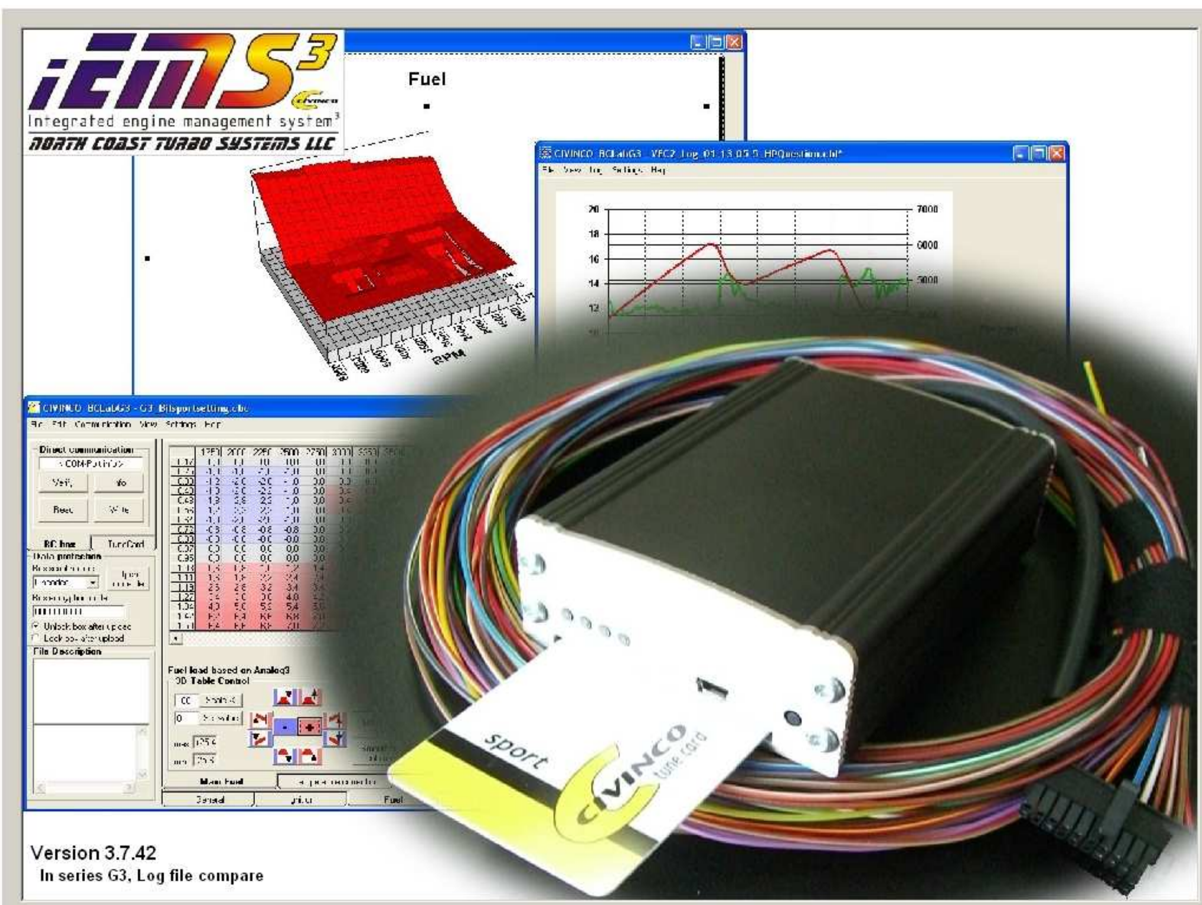
amounts of heat as it vaporizes into steam, reducing peak temperature and resultant NOx formation, and reducing the amount of heat energy absorbed into the cylinder walls.

The alcohol in the mixture burns, but is also much more resistant to detonation than gasoline. The net result is a higher octane charge that will support very high compression ratios or significant forced induction pressures before onset of detonation.

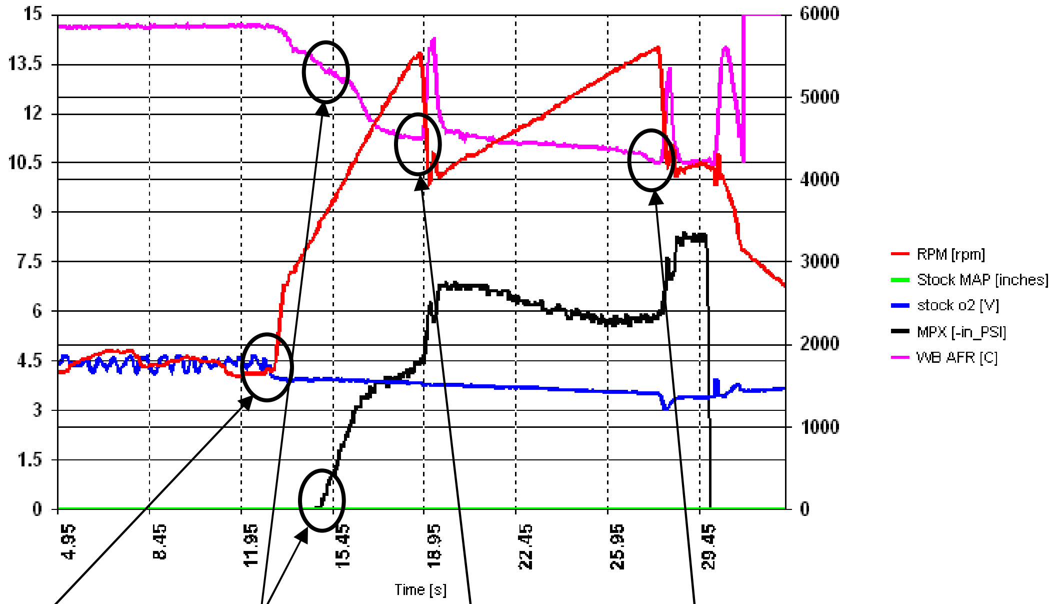
With the introduction of the intercooler the interest in water injection disappeared, but today, water injection is also of interest because it can potentially decrease nitrogen oxide (NO_x) emissions in exhaust.

The most common use of water injection today is in modern vehicles with aftermarket forced induction systems, such as turbochargers or superchargers. Such engines are commonly tuned with a narrower margin of safety from detonation and therefore benefit greatly from the additional cooling effects of vaporized water/methanol.

We have found that the additional cooling benefits of the water/methanol injection system to be invaluable in maintaining manageable combustion temperatures in the cylinders, thereby preventing detonation and potential engine damage. This is why all of our turbocharger systems incorporate water/methanol injection into the overall design.



iEMS2 Engine Management System Fuel Correction Datalog. 2006 Chrysler 300C, 5.7L Hemi engine.



System senses rapid parameter change, takes control of O2 sensors as evidenced by flatline drop in O2 voltage applying preliminary fuel correction prior to onset of boost.

At boost onset, AFR has already reached 13.2 and is plunging as the system transitions over to full injector pulse width control.

Prior to 1st to second shift, AFR has reached 11.1 and continues to plunge following shift point, boost reaches 6.5 psi after shift.

Prior to 2nd shift, AFR has reached 10.5 and flatlines following the shift point, boost reaches 7.5 psi at shift and goes to 8.5 following the shift with steady AFR.

This is the very first boosted run following the installation of the iEMS2, and after less than 1.5 hours of setup and initial mapping setup. All tuning was performed without the use of a chassis dyno. Initial dyno readings were 411 RWHP and 500 RWTQ at 6.5 – 7 psi boost on an all stock internals 5.7 Hemi.

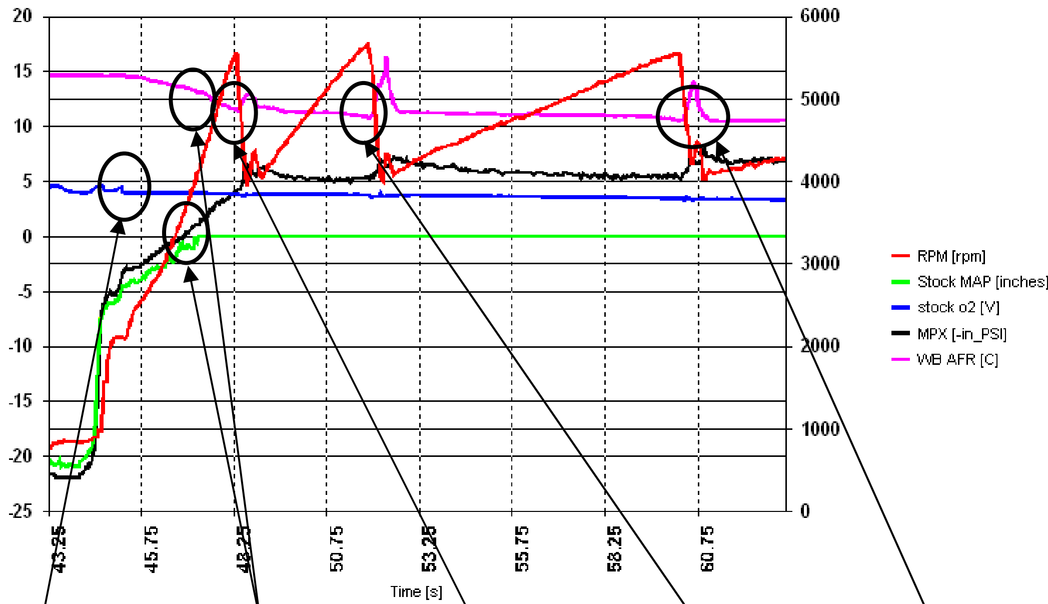
All tuning based on the original factory ECU programming.

Wideband AFR data was fed from a PLX R300 output to the iEMS3 for datalogging. Datalog is captured via the iEMS3 logging window.

The current version of the iEMS unit is G3 (generation 3), which added:

- Complete 3D map for fuel and ignition.
    - Selectable Map size.
    - Ability to select span between load and rpm cells.
- One extra PWM-output in IS8G3
- One (IS4G3) or two (IS8G3) tuneable digital outputs to control Vanos, Vtec, gear indicator etc.
- Cold start function for easy tuning of E85.

iEMS2 Engine Management System Fuel Correction Datalog. 2006 Chrysler 300C, 5.7L Hemi engine.



System senses rapid parameter change, takes control of O2 sensors as evidenced by flat line drop in O2 voltage applying preliminary fuel correction prior to onset of boost.

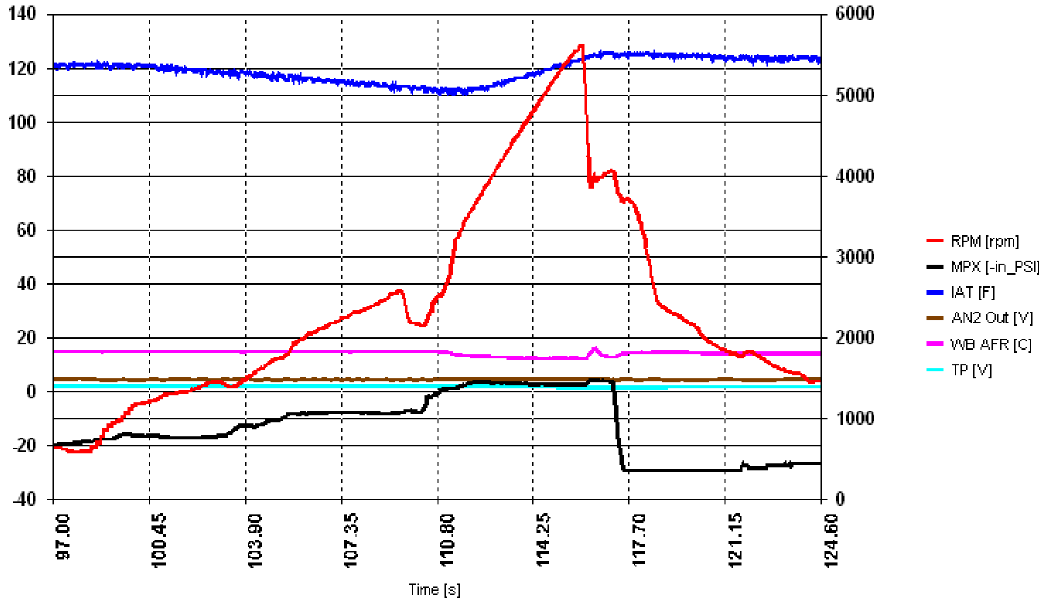
At boost onset, AFR has already reached 12.7 and is plunging as the system transitions over to full injector pulse width control. This graph also shows stock MAP sensor clamped at 0 inches of vacuum.

Prior to 1st to second shift, AFR has reached 11.1 and continues to plunge following shift point; boost reaches 6.5 psi after shift.

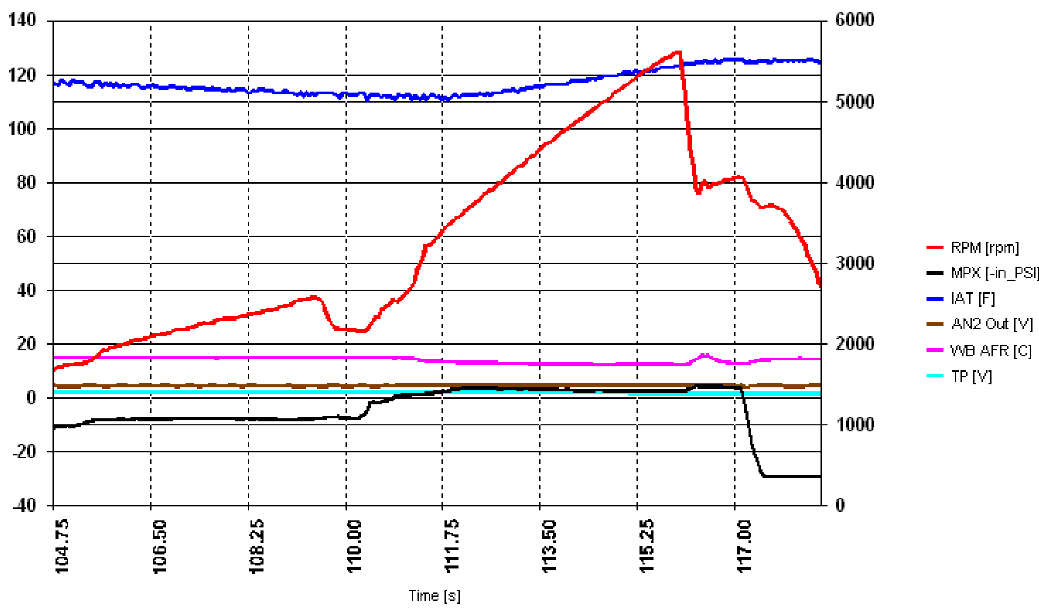
Prior to 2nd shift, AFR has reached 10.5 and flat lines following the shift point, boost reaches 6.5 psi at shift. AFR remains steady through run up to 3rd gear shift point and remains steady through beginning of 4th gear run up.

Following 3 - 4 shift, boost is increased to 7.5 psi and AFR continues to hold steady at 10.5 during 4th gear run up.

iEMS2 Engine Management System Part Throttle Boost Fuel Correction Datalog. 2006 Chrysler 300C, 5.7L Hemi engine.



View above is an overall view of the subject time period, the view below is a zoom detail view providing detail of the transition into part throttle (Closed Loop) low boost operation. Note, the vehicle remained in closed loop at all times and did not transition to Open Loop (WOT).



At 104 seconds, tip in is started by slowly easing into the pedal. Just before 110 seconds, vehicle disengages from 5th overdrive and drops into 4th gear and begins a slow steady increase in rpm.

Just before 111 seconds, system senses the approach to boost threshold and takes control of the O2 sensors and begins to increase fuel and the AFR. This can be seen by the ripple of the AN2 out (O2) line going to a flat line.

The AFR line starts to trend downward as fuel is increased.

At 111 seconds, vehicle transitions into low boost, there has been minimal pedal movement and the vehicle is experiencing a slow gradual increase in speed and rpm with a smooth transition from vacuum to a boosted state.

Data from 110 seconds during the downshift, -7.71 inches of vacuum and AFR 14.67;

RPM [rpm] - 110.00s ; 2168.4
MPX [-in_PSI] - 110.00s ; -7.71
IAT [F] - 110.00s ; 113
AN2 Out [V] - 110.00s ; 3.95
WB AFR [C] - 110.00s ; 14.67
TP [V] - 110.00s ; 1.74

Data from 111 seconds following downshift, boost pressure is 2.06 psi and AFR is 13.1;

RPM [rpm] - 111.75s ; 3408.2
MPX [-in_PSI] - 111.75s ; 2.06
IAT [F] - 111.75s ; 110.75
AN2 Out [V] - 111.75s ; 4.28
WB AFR [C] - 111.75s ; 13.1
TP [V] - 111.75s ; 1.7

Data from 113 seconds, boost pressure is 2.8 psi and AFR is 12.27;

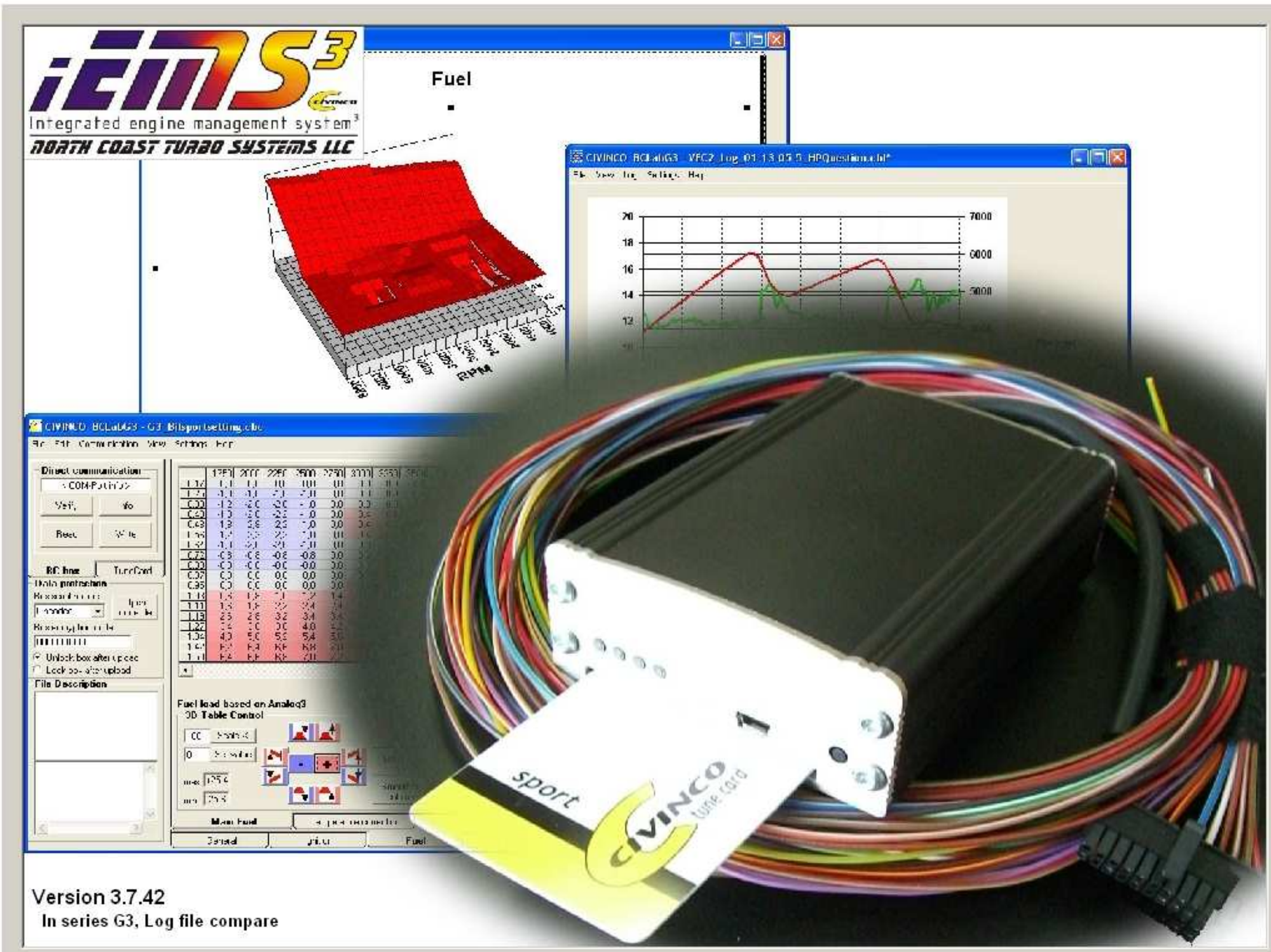
RPM [rpm] - 113.50s ; 4400.3
MPX [-in_PSI] - 113.50s ; 2.8
IAT [F] - 113.50s ; 115.5
AN2 Out [V] - 113.50s ; 4.24
WB AFR [C] - 113.50s ; 12.27
TP [V] - 113.50s ; 1.5

Data from 115 seconds, boost pressure is 2.21 psi and AFR is 12.08

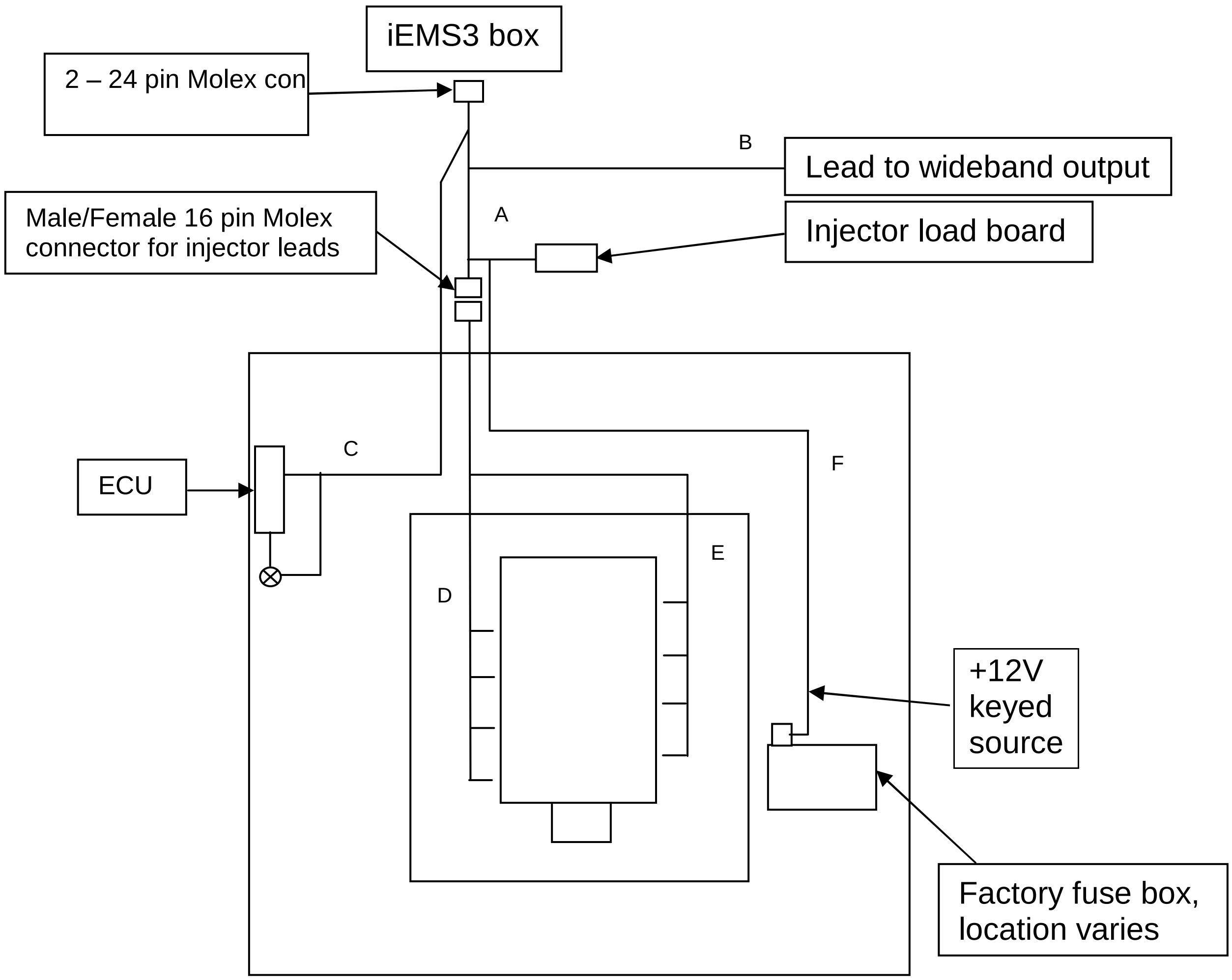
RPM [rpm] - 115.30s ; 5328.1
MPX [-in_PSI] - 115.30s ; 2.21
IAT [F] - 115.30s ; 120.5
AN2 Out [V] - 115.30s ; 4.2
WB AFR [C] - 115.30s ; 12.08
TP [V] - 115.30s ; 1.33

Data from 117 seconds, boost pressure is 3.53 psi and AFR is 12.55, this is following the up shift, and release of the pedal immediately before rpm and boost falls off back to a vacuum state. The AN2 (O2) sensor voltage immediately goes back to a ripple as the system returns to normal operation.

RPM [rpm] - 117.00s ; 4046.8
MPX [-in_PSI] - 117.00s ; 3.53
IAT [F] - 117.00s ; 125.5
AN2 Out [V] - 117.00s ; 4.16
WB AFR [C] - 117.00s ; 12.55
TP [V] - 117.00s ; 1.29

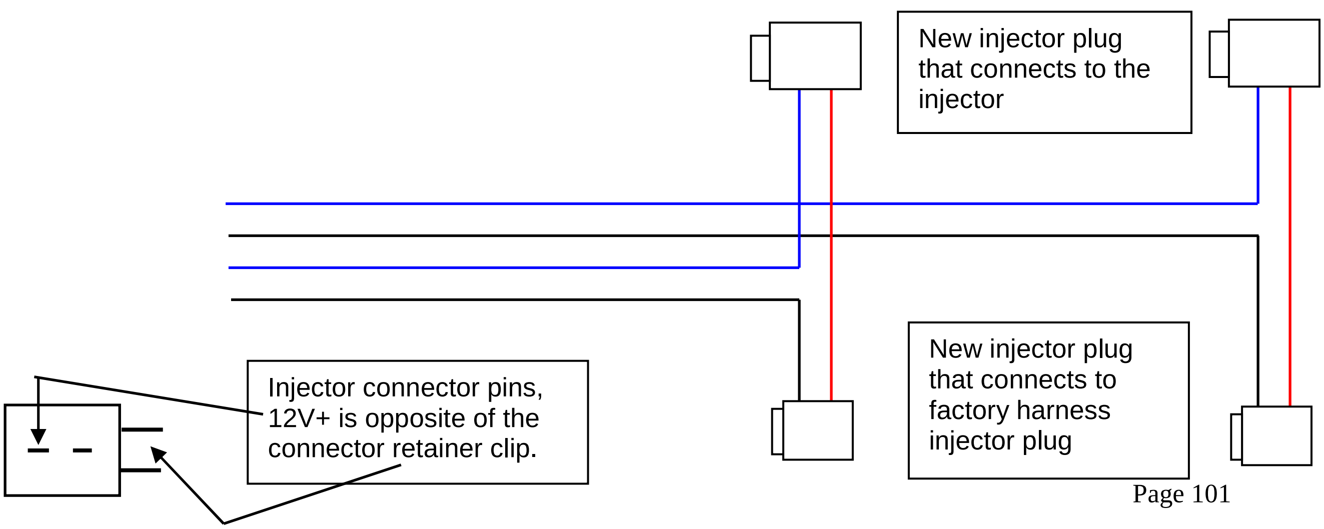


Typical electrical schematic for the iEMS3 IS8G3 “In Series” unit.

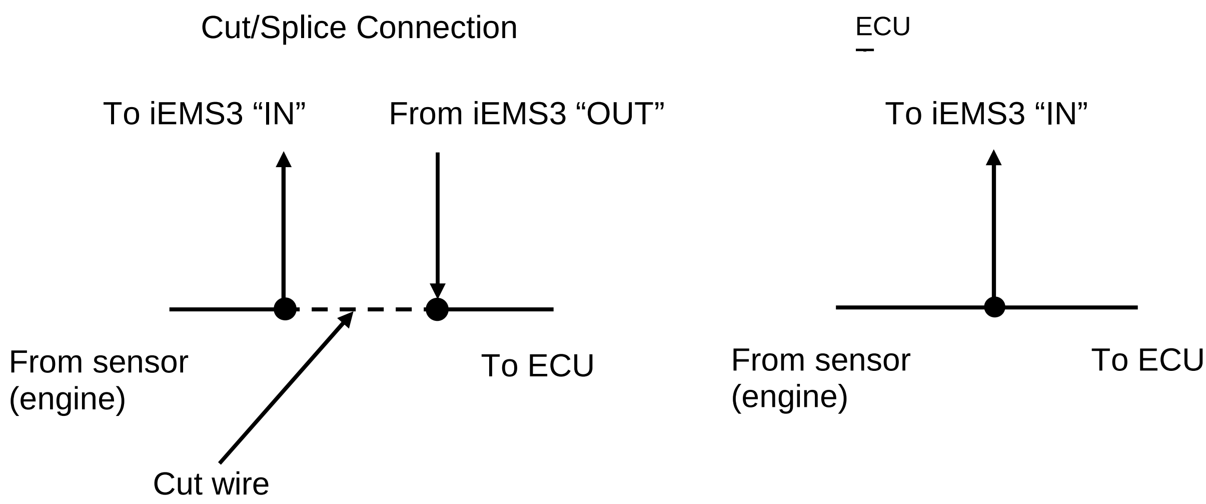


⊗ - Ground stud

Red lead is +12V jumper from one plug to the opposite plug
Black lead is input from factory injector harness to the iEMS3
Blue lead is new output from iEMS3 to injector



All splices must be soldered; Crimp style T-Taps and butt splices are NOT to be used due to potential for wire damage and increased wire resistance.



Care must be taken with the Molex Mini-Fit connectors that connect the iEMS3 harness to the iEMS3 unit. You want to minimize the amount of back and forth movement of the pins in the connectors. After you have determined the final wiring configuration (optional leads inserted in the connectors), you can use a thick gap filling CA (instant) adhesive in the end of the connector where the wire exits to anchor the lead if desired. Do not use the thin watery type of adhesive if you decide to do this.

It is important to power the iEMS3 unit directly from the lead that supplies 12 volt + power to the vehicle ECU. This is to ensure the ECU and iEMS3 power up at the same time, as some vehicles take a barometric pressure update within the first few milliseconds on power up. If the iEMS3 is not online, you may receive a low MAP sensor voltage code (clear the code and start the vehicle).

If this is an issue, we have an inexpensive timer circuit available that can be tapped into the interior light circuit so that as soon as the door opens it triggers the timer which will put power first to the iEMS3 and can be set to drop out after several minutes (1-60 minutes) giving plenty of time for the vehicle to be started and the normal power to be supplied to the iEMS3.

In some vehicles, the ECU may be powered through an ASD (Auto Shut Down) relay system. Some vehicles will produce an ASD relay trouble code if the ECU is sensitive enough to detect additional draw on the ECU power circuit. Due to this, **DO NOT** connect the injector load board power lead to the ECU power supply, Connect to a separate key on power source.

Mount the iEMS3 in a convenient location for access to change tunes. Flying lead harness has 3 meter length leads, however keep the leads as short as practical. If iEMS3 is located in the console for example, consider wrapping the non power leads with shielding foil or foil covered convoluted split tubing in the passenger compartment.

DO NOT insert optional leads into the iEMS3 connectors unless the function will be used.

We can create a custom modular harness for your application if you can supply the required dimensions. This would include heavy duty plugs where the main harness enters the engine compartment, splitting the harness into two sections. Please inquire regarding cost and availability.

<u>A includes, iEMS3 Box</u>

8 – inj lead in (from male injector plug that plugs into existing injector connector)
8 – inj lead out (from iEMS3, plugs into the injector)
1 – +12v power in (power from 12v key on power circuit, T splice)

<u>B includes, wideband input lead</u>

1 – wideband controller optional output, in to iEMS3 (if used, optional)

<u>C includes, PCM</u>

1 – +12v power in (power from ECU 12v power circuit, T splice)
2 – -12v chassis ground in (Both chassis grounds should be taken to a substantial chassis ground location) close to the iEMS3 unit as possible, or to the ECU ground stud..
2 – Factory MAP sensor in/out (cut original lead)
2 – Crank sensor in/out (cut original lead)
2 – Factory O2 sensor return lead in/out (cut original lead)
2 – Cam sensor in/out (if used) (cut original lead)
1 – IAT sensor input (if used, optional, T-splice)
1 – TPS input (if used, optional, T splice)
2 – -12v signal ground in (connect both grounds to the ECU sensor ground).
1 – Shift light output (if used, optional)
1 – PWM Boost control out (if used, optional)
1 – PWM Water/meth out (if used, optional, must use power switch)

<u>D includes, even cylinder bank</u>

2, 4, 6, 8 injector leads (4 in, 4 out)

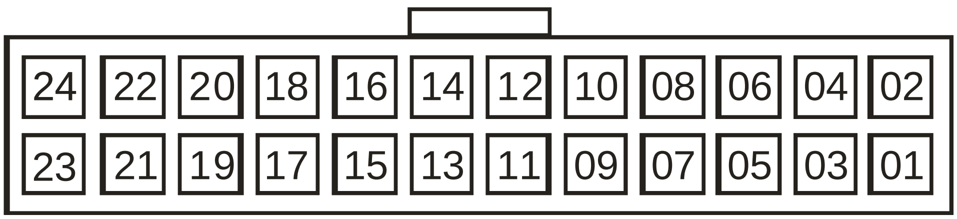
E includes, odd cylinder bank

1, 3, 5, 7 injector leads (4 in, 4 out)

F includes, injector load board

+12v key on source to fuse box

Note: The injector load board has 10 injector leads (8 used), and 1 +12 volt power source. The 8 injector leads are T-spliced into the 8 injector leads that feed into the iEMS3 unit. 2 are unused.



LOOKING AT WIRE SIDE OF CONNECTOR

Pin configurations above is typical for the iEMS3 24 pin Molex Connectors that plug into the unit.

Load Board:

The red wire on the load board is connected to a switched 12v source. There is no ground lead. The fuel signal wires that leads from the ECU to the iEMS3 fuel inputs needs the load board to simulate that there are injectors connected to it now when we are driving the injectors with the iEMS3. There are 10 input wires on the load board, only eight are used for a V8 engine. Each wire is an individual circuit, so it does not matter which are used in any particular order.

Power Switch:

black - Chassis ground
red - 12volt power in
white - 12volt power out - The pump can be powered from another source. In that case this wire would not be used.
white/black - Grounding output
thin black/yellow or black/green - in signal. It can be a PWM from the iEMS3. When this is grounded the white/black output of the power switch is also grounded

M=Master
S=Slave

Typical pin function assignment for Chrysler/Dodge/Jeep	
PWM1 - M-5	Boost control (open or closed loop mode)
PWM2 - S-5	Water/Methanol or other high amperage load using power switch
An2 in - M-8	From O2 sensor
An2 out - M-7	O2 sensor signal to ECU
An4 in - M-4 and S-4	IAT connects to master and slave when used for tuning
M-11	camshaft out
M-12	camshaft in
M-13	crankshaft out
M-14	crankshaft in
S-14	crankshaft in
An3 in M-6 and S-6	**Internal MPX MAP sensor**
An1 in M-10	Stock MAP sensor signal from sensor
An1 out M-9	Stock MAP signal to ECU
AN2 in S8	Throttle position - only for monitoring value
An1 in S-10	Analog sensor for monitoring any 0-5 v signal
Digital 1 out	Switched grounding output. Can be based on rpm and/or any analog sensor.
Digital 2 out	Switched grounding output. Can be based on rpm and/or any analog sensor.
	If you need to connect to oxygen sensors on both banks: An2in - S-8 from o2 sensor An2out - S-7 o2 sensor signal to ECU
	If Camshaft Signal is not used, then M11/M12 analog pair are available for other use.

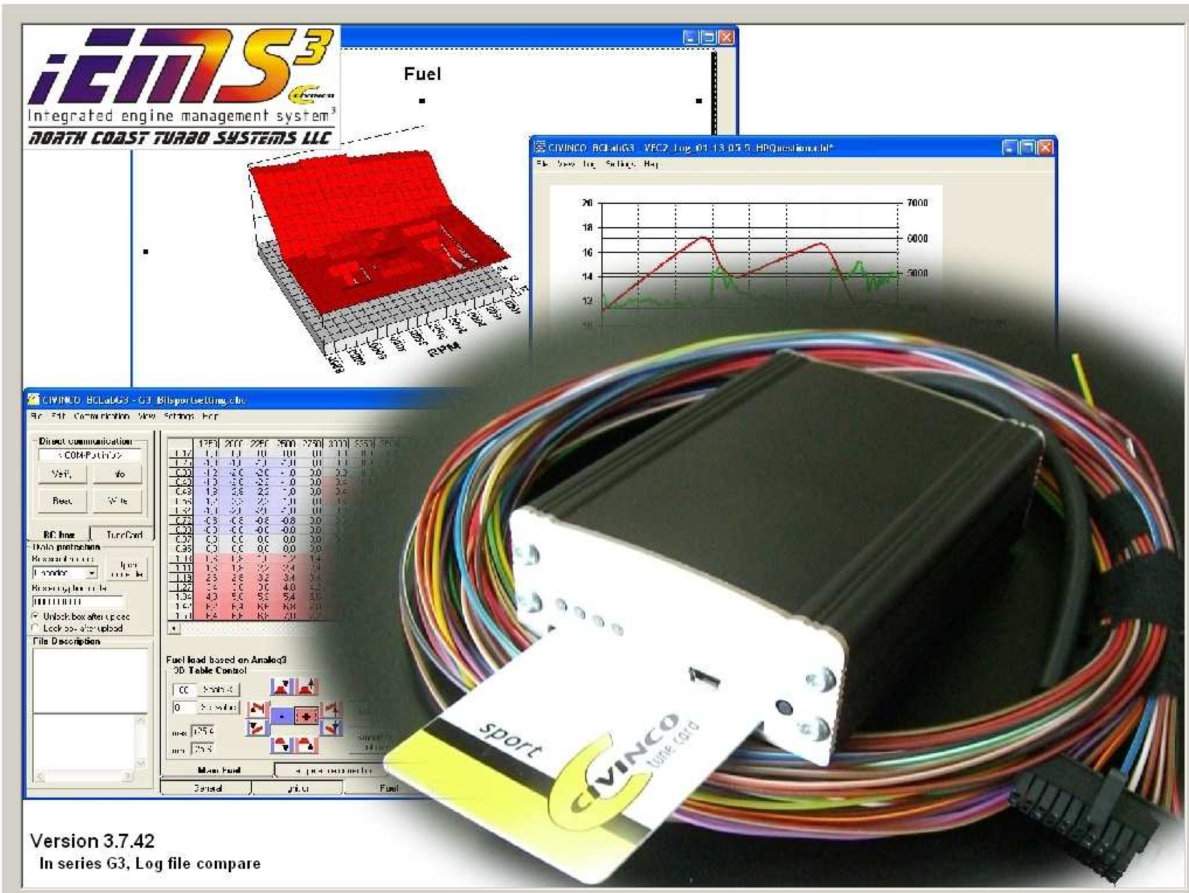
The iEMS3 uses PIC microprocessors that are programmed "close to hardware". All critical timing issues are executed in assembler language. This is the best method for engine management systems as the code is highly efficient, keeping the response time (interrupt to action) minimized.

iEMS3 IS8G3 - TECHNICAL SPECIFICATIONS

GENERAL	
WEIGHT	310 g
SIZE (LxWxH)	111 x 82 x 35 mm
POWER INPUT	7 V to 17 V
POWER CONSUMPTION	12 V / 120 mA
CPU	Microchip PIC running @ 40 MHz
CABLE CONNECTOR	2 x 24-pin
STATUS LED	Power, RPM indicator, TuneCard wr/rd active, TuneCard ok
OPERATING TEMPERATURE	-40℃ to +85℃ (-40℉ to +185℉)
TUNECARD	All settings can be stored on TuneCard for easy change of settings
	TuneCard memory size – 16kb
DATA LOGGER	Aquire data to a PC, standard frequency 20 Hz – 50 parameters
DIGITAL OUTPUT RESOLUTION	0.8 micro seconds
FUEL	
CHANNELS	8 input, 8 output
CURRENT	3A grounding
FUEL CHANGE SPAN	-25 to +25 ms (normally based on engine load and rpm)
	3D map with fully adjustable axis
	Ability to run extra injectors
	Fuel cut RPM
	Injector change calibration – run from half size to 4x larger than stock injectors
IGNITION	
CHANNELS	4 input, 4 output
CURRENT	3A grounding, 100mA to 5v
	3D map with fully adjustable axis
SIGNAL LEVEL	12 V / 5 V
CURRENT	3A grounding, 100mA to 5v
TIMING CHANGE SPAN	-25 to +25° (normally based on engine load and rpm)
ANALOG MAP / MAF	
CHANNELS	4 input, 2 output
	Analog 1 out limit depending on RPM
	Analog 2 out limit depending on RPM
	Analog2 out, function of analog2 in
	Analog2 out, boost activated analog output
PWM out/DIGITAL out	
CHANNELS	4 output
	PWM1 out based on analog sensor and RPM w. closed loop boost control
	PWM2 out based on analog sensor
	Digital1 and Digital2 out, based on RPM and analog sensor
EXTERNAL SENSOR POWER	
VOLTAGE	5V
CURRENT	25 mA

Performance Tuning for the Modern OBDII Compliant Vehicle

By North Coast Turbo Systems LLC



North Coast Turbo Systems LLC
4075 East Kirk Road, #17
Port Clinton, OH 43452
419-573-2122

www.northcoastturbosystems.com

www.iems3.com

info@northcoastturbosystems.com
tech@northcoastturbosystems.com
sales@northcoastturbosystems.com
dealer@northcoastturbosystems.com